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Forage Potential of Seasonal Wetlands

Daniel Edward Hubbard

FORAGE POTENTIAL OF SEASONAL WETLANDS

BY

DANIEL EDWARD HUBBARD

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This dissertation is approved as a creditable and independent investigation by a candidate for the degree, Doctor of Philosophy, and is acceptable for meeting the dissertation requirements for this degree. Acceptance of this dissertation does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

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Investigations on aspects of seasonal wetland forage potential were conducted in eastern South Dakota. The quantity and quality of the standing crop of vegetation in 6 seasonal wetland communities were assessed at the end of the growing season in 1983 and in 2 seasonal-wetland-dominated basins and their associated uplands (native mixed-grass prairie) over the growing season in 1985. Crude protein (CP), ash, detergent fiber, and *in vitro* digestible dry matter (IVDDM) values were measured on the above-ground material of whitetop [*Scolochloa festucacea* (Willd.) Link], slough sedge (*Carex atherodes* Spreng.), burreed (*Sparganium eurycarpum* Engelm.), and smartweed (*Polygonum amphibium* L. var. *emersum* Michx.) at intervals during the growing seasons of 1984 and 1985. Concurrent measurements of the total nonstructural carbohydrate (TNC) content of below-ground material of these 4 species were also made. An additional 27 species were collected during the summer seasons of 1984 and 1985 for CP, ash, and IVDDM analyses.

Season-long comparisons of wetlands and uplands show that, on an area basis, seasonal-wetland-dominated basins produce higher standing crops of forage than uplands in a native mixed-grass prairie situation. The large late-season standing crop estimates (679 to 1146 $g \cdot m^{-2}$) in 6 seasonal wetlands, as well as values in the literature, suggest that most seasonal wetlands probably do yield higher standing crops (on a

single cutting basis) than native mixed-grass prairie or cultivated cool-season grasses. However, the digestibility of the dominant wetland forages is lower, on the average, than native upland forage. Several subordinate forb species were found to have high IVDDM and CP values during mid-summer and may be potential candidates for a wetland forage breeding program. Seasonal-wetland-dominated basins should be utilized early in the growing season to optimize forage quality.

CP and IVDDM contents of whitetop and slough sedge were comparable to most grasses at similar phenological stages. At mid-summer, however, the nutritional quality of these 2 species is low and would make a hay adequate only as a base roughage. Whitetop nutritional quality is very poor during the latter portion of the growing season, while the quality of slough sedge is maintained at an adequate level for a longer period. TNC reserves in below-ground material of these 2 species are lowest during the approximate periods of tillering and flowering (early June). Utilization at seed-fill for whitetop and just post-seed-fill for slough sedge will avoid the period of low TNC reserves and yet yield an acceptable quality forage. Burreed, on the other hand, is a species that may be considered for control in seasonal wetlands. The TNC content of below-ground material of burreed is at its lowest near the onset of flowering. Therefore, control measures should be implemented at that time.

If utilized early in the growing season, seasonal wetlands are capable of producing some good quality forages. If utilized in the latter part of the growing season, forage quality may be low but yields are high. With appropriate supplementation, these forages could be used as roughages in domestic livestock rations. Utilization of wetlands for forage production is a use more compatible with other wetland functions than is the artificial draining of them and planting to annual crops.

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Chapter 1

INTRODUCTION

The glaciated northern prairie region, commonly referred to as the "Prairie Pothole Region," extends from northern Iowa, through portions of Minnesota, South Dakota, North Dakota, Montana, Manitoba, Saskatchewan, and Alberta. The late stages of Wisconsin age glaciation are responsible for the depressional topography of the region (Flint 1955, Lemke et al. 1965). The millions of depressions in the region typically contain a wetland, of some sort, at the toeslope. The wetlands range in size from a fraction of a hectare to hundreds of hectares. Although significant areas of wetland exist along drainage-ways in the region, most are depressional, or basin wetlands (Stewart and Kantrud 1973, Ruwaldt et al. 1979). These depressional wetlands are commonly referred to as sloughs or potholes.

The most well known aspect of the ecology of prairie potholes is their importance to the continental waterfowl population. This region comprises only 12% of the continental breeding waterfowl habitat, but from 1955 to 1977 it was occupied by 41% of the breeding dabbling duck (Anatidae) population (Bellrose 1979). In addition to their continental significance to ducks, potholes are important habitat components of many resident wildlife species (Schitoskey and Linder 1979, Linder and Hubbard 1982). It has been estimated that as a recreational resource for resident hunters, South Dakota wetlands were worth $813.00/ha to the state's economy in 1982 (Johnson and Linder 1986).

The artificial drainage of prairie wetlands for agricultural production has concerned waterfowl biologists for many years. Over 95% of Iowa's wetlands have been drained (Bishop 1981). The most recent loss estimate available for North Dakota is 60% and for South Dakota is 35% (Tiner 1984).

Loss of waterfowl habitat is not the only public concern related to wetland drainage. The doubling of flood frequencies on the Red River of the North since 1950, as compared to the previous 58 years, has been tentatively blamed on wetland drainage (Rannie 1980). Brun et al. (1981) documented the permanent increase in the runoff contributing area to tributaries of the Red River due to depression drainage. These authors also demonstrated increased streamflows over time that could not be attributed to increased precipitation patterns. Several hydrologic modelling studies have provided further evidence of increased watershed discharge due to depression drainage (DeBoer and Johnson 1971, Campbell and Johnson 1975, Moore and Larson 1979). However, one modelling study conducted in southern Saskatchewan to address flooding per se found that wetland drainage contributed to increased flood peaks (Dybvig and Hart 1977). Not only does wetland drainage circumvent the runoff storage potential of the depressions, but it precludes groundwater recharge.

Generally, recharge of the groundwater in the surficial deposits of the glaciated prairie region does not occur over the entire soil surface, but occurs in the depressions where water is ponded (Freeze and Banner 1970, Lissey 1971, Malo 1975). However, many wetlands are groundwater discharge sites and some are flow-through systems (Sloan 1972, Winter and Carr 1980). The latter type recharges and discharges groundwater at various points within the basin. Some wetlands can change from one type to another depending on fluctuations in the water-table (Lissey 1971, Sloan 1972, Winter and Carr 1980). Although it remains to be adequately addressed by the scientific community, the drainage of wetlands could be detrimental to the long-term water balance and agricultural stability in this subhumid to semiarid area of the Dakotas and Canadian provinces (MacLeod 1977). It has been demonstrated that at landscape positions where the water-table is within about 2.7 m of the surface, soil moisture can be recharged to a significant degree due to upward movement of water from the surface of the water-table in response to thermal gradients during winter (Schneider 1961, Benz et al. 1968, Malo 1975). A hydrologic modelling study in Iowa (Campbell and Johnson 1975) has predicted significantly higher soil moisture levels in the top 1.5 m of soil under corn throughout the growing season within an undrained depressional watershed versus a completely drained watershed.

The potentially high economic value of wetland functions to society may outweigh their value after drainage and conversion to row crop or small grain production (Heimlich and Langner 1986). In order to conserve these natural resources, incorporating their inherent values into farming operations may be a desirable means to preserve prairie wetlands. The U.S. Department of Agriculture (USDA) has recently taken steps toward this end by denying farm program benefits to operators engaging in new wetland conversions (Heimlich and Langner 1986). It may even be profitable to conserve wetlands. Many wetlands in the pothole region are drained regardless of the cost effectiveness — merely for the convenience of maneuvering large farm equipment (Leitch and Danielson 1979, Heimlich and Langner 1986).

The vegetative biomass produced in wetlands is a commodity of potential agronomic use. Wetlands throughout the world are regarded as highly productive systems (Westlake 1963, Keefe 1972).

Wetlands are utilized by landowners in South Dakota as sources of hay or forage for livestock. It has been estimated that about 24% (ca. 75,400 ha) of the wetland hectarage in 17 northeastern South Dakota counties were hayed in 1980 (U.S. Fish and Wildlife Service 1980). A nonrandom survey of wetland complexes in these same 17 counties in the fall of 1980 revealed that 16.7% of the undrained Type 3 and 4 (classified according to Shaw and Fredine 1956) wetland basins observed were hayed and 45.1% were grazed (Wittmier 1982). A 5% sample of the Yellowbank River watershed and a 1% sample of the upper Big Sioux watershed in South Dakota by Wittmier and Mack (1982) found that 45% and 28% of the wetland hectares, respectively, were utilized for livestock forage (either hayed or grazed) in 1981. A random sample of 168 sections in the Big Sioux, Vermillion, and Minnesota River watersheds in South Dakota revealed that 18% of the total wetland area occurring in those sections was hayed or grazed in 1982 (Wittmier 1984). However, when the total wetland area was broken down by water-regime (classified according to Cowardin et al. 1979), it was found that 48% of the hectarage of the seasonal-wetland-dominated basins occurring on the 168 sections were utilized for forage. Seasonal wetlands accounted for 23% of the wetland area in that study. The majority of the area of temporary-wetland-dominated basins in those watersheds were tilled while most of the semipermanent wetland area was unutilized. A 1.3% random sample of sections in the upper James River watershed in South Dakota (Wittmier 1985) found that 51% and 22% of the hectarage of seasonal-wetland-dominated basins were grazed and hayed, respectively, in 1984. Seasonal-wetland-dominated basins accounted for 54% of the existing wetland area in the sample. The majority of temporary- and semipermanent-wetland-dominated basins were likewise tilled and unutilized, respectively, in this watershed.

While the above data indicate that wetlands, especially seasonal wetlands, are being used as sources of livestock forage there is virtually no information available on the quantity or quality of forage produced in South Dakota wetlands. Several studies have reported emergent wetland standing crops in other states and provinces in the glaciated prairie and parkland regions (Cosby 1964, McNaughton 1966, Hadley 1970, Smeins and Olsen 1970, Smith 1973, Corns 1974, Gorham and Bernard 1975, van der Valk and Davis 1978, 1980, Fulton et al. 1979, Fulton and Barker 1981, Neckles et al. 1985). Most of these studies, plus several others including unpublished studies, have been recently summarized by Fulton et al. (1986). Only one study, which lists standing crop data of a cattail (Typha sp.) stand (a semipermanent wetland species) near Watertown, has been conducted in South Dakota (McNaughton 1966). For appropriate discussion and comparative purposes, wetland standing crop data need to be collected from South Dakota.

Along with data on the production of emergent wetland plants, data on their nutritive composition are needed so that the more nutritious species can be identified. Seasonal variation in composition also needs to be documented. Data on 32 species of emergent plants that occur in South Dakota wetlands have been located and summarized in Linder and Hubbard (1982) and Fulton et al. (1986). These data show that, at least based on proximate analyses, many emergent wetland species are comparable to many upland forages. But, unfortunately, many of these studies have been conducted outside of the prairie pothole region and none have been conducted in South Dakota. Data on the digestibility of various organic components of 10 species and 15 species-mixtures that occur in the region are summarized in Fulton et al. (1986). However, digestibility data on only 4 of these species were collected in the prairie pothole region in North Dakota and Saskatchewan.

In addition to ascertaining which marsh plant species have potential for good forage production and which do not, information on the proper management of wetland species needs to be compiled in order to assist landowners in developing proper harvest techniques and schedules. Proper scheduling of grazing or cutting can be facilitated by the knowledge of the annual carbohydrate cycle of the plants (Smith 1972, White 1973). Information on the seasonal changes of total nonstructural carbohydrates (TNC) in the rhizomes of some wetland species is available, e.g., Carex lacustris (Roseff and Bernard 1979; a common species in other parts of the U.S., but rare in this area), Spartina alterniflora (Lytle and Hull 1980; a common coastal saltmarsh species), Phragmites australis (Fiala 1976; a common world-wide species that occurs in fens in this area), Typha spp. (Fiala 1971, Linde et al. 1976, Kausch et al. 1981; a world-wide genus common in semipermanent wetlands in this area), and Phalaris arundinacea (Wolf 1967; a common introduced, but also native, grass in seasonal wetlands of this area). However, information on the seasonal TNC content of rhizomes of most prairie wetland species is not available.

Information on yields, nutritional quality, and proper management of wetland plant species needs to be obtained before accurate statements regarding the direct benefits of wetland forage utilization can be made. To assemble this information on all of the possible wetland plant communities occurring in South Dakota would involve a massive expenditure of funds and manpower. In order to obtain accurate and meaningful information on wetland forage, this study will of necessity focus on only one type of wetland. The data collected by Wittmier and Mack (1982), Wittmier (1984), and Wittmier (1985) show that in the watersheds they studied in eastern South Dakota, wetlands with seasonal water-regimes dominating the basin were utilized more (proportionately) than either temporary or semipermanent wetlands for livestock forage. Hence, for this study of wetland forage, representative plant communities of palustrine emergent seasonal wetlands (classified according to Cowardin et al. 1979) will be studied.

Palustrine emergent seasonal wetlands as classified by Cowardin et al. (1979) (the "Cowardin system") are generally synonymous in the glaciated prairie region with the shallow marsh zone described by Stewart and Kantrud (1971) (Cowardin et al. 1979, Cowardin 1982). The system of classification developed by Stewart and Kantrud (1971) is specific for the depressional wetlands of the glaciated prairies and is the one most often used in literature since its publication. In that system, basins that contain a shallow marsh zone in the central (i.e., deepest) portion are termed Class 3, or seasonal, wetlands. The term "seasonal" in that system refers to the whole wetland contained within the depression and includes (typically) a peripheral zone of wet meadow. A basin occupied in the deepest portion by a wet meadow zone is termed a Class 2, or temporary, wetland. A Class 4, or semipermanent, wetland contains a central zone of deep marsh, typically surrounded by zones of shallow marsh and wet meadow. Thus, the system of Stewart and Kantrud (1971) is based on a physiognomic concept and the terms temporary, seasonal, and semipermanent each refer to the entire set of zones that occur within a depression.

The nation-wide classification system developed by Cowardin et al. (1979) is based on an area concept and each of the zones described by Stewart and Kantrud (1971) are equivalent to individual wetlands in the Cowardin system. All depressional wetlands, except deep lakes, in this region are in the palustrine system and are either in the emergent class or aquatic bed class of the Cowardin system. The most useful level of differentiating between kinds of wetlands in this region is at the water-regime modifier level of the Cowardin system. The most prevalent water-regimes of the region are temporary (ponding occurs for only brief periods during the growing season in a normal year), seasonal (ponding typically occurs for extended periods in a normal year, but is usually dry by the end of the growing season), and semipermanent (ponding occurs throughout the growing season in most years). These water-regimes are equivalent to the wet meadow, shallow marsh, and deep marsh zones, respectively, of the Stewart and Kantrud (1971) system.

Throughout the remainder of this document the Cowardin system will be used, and usually only the water-regime will be specified. However, it will be necessary at times to differentiate between (1) a seasonal wetland that occurs as a peripheral wetland around a semipermanent wetland, and (2) a seasonal wetland that occupies the central portion of a depression. In these instances, the term "seasonal-wetland-dominated" basin or pothole (viz., Class 3 of Stewart and Kantrud 1971) will be used for the latter and a "peripheral seasonal wetland" will be used for the former.

The general objective of this study was to evaluate the forage potential of representative seasonal wetlands in eastern South Dakota. To accomplish this, more specific objectives were to (1) document standing crops of vegetation in selected seasonal wetlands and estimate the nutritional quality of the biomass (Chapter 2), (2) evaluate the seasonal variation in nutritional quality of selected common dominant plant species in seasonal wetlands (Chapter 3), (3) evaluate the suitability of several chemical attributes (crude protein, ash, acid detergent fiber, neutral detergent fiber, and lignin) as indices to digestibility of several dominant species (Chapter 3), (4) measure the seasonal variation in total nonstructural carbohydrate (TNC) content of selected dominant plant species (Chapter 3), (5) collect some nutritional quality information on selected other species of plants found in seasonal-wetland-dominated basins (Chapter 4), (6) evaluate the effects of mowing on selected seasonal wetland plant stands (Chapter 5), and (7) compare the standing crop and nutritional quality of selected seasonal wetlands with their associated uplands (Chapter 6).

Chapter 2

LATE-SEASON STANDING CROPS AND NUTRITIONAL QUALITY IN SELECTED SEASONAL WETLANDS IN EASTERN SOUTH DAKOTA

Introduction and Objectives

Several studies have reported vegetation standing crops in glaciated prairie wetlands, but none have reported seasonal wetland standing crops in South Dakota (see Chapter 1). Likewise, although some nutritional data exist for wetland plant species that occur in this area, there are no reports of nutritional quality of wetland plant species in South Dakota (see Chapter 1). The objectives of this study were to document the late-season above-ground standing crop and nutritional quality of vegetation in selected stands of seasonal wetland plants.

Study Areas

Six stands of seasonal wetland vegetation were selected on public lands in eastern South Dakota during late summer 1983. All were dry at time of selection and when harvested. Two seasonal-wetland-dominated basins (Sites 1 and 2) were on the Seversen Waterfowl Production Area (WPA) (NW 1/4, Sec. 5, T 114 N, R 47 W) in Deuel County, and another (Site 3) was on the Brookings WPA (NW 1/4, Sec. 16, T 111 N, R 52 W) in Brookings County. Site 4 was on the Lake Cochran Recreation Area (NE 1/4, Sec. 4, T 117 N, R 47 W) in Deuel County and while historically it may have been a semipermanent-wetland-dominated basin, it is now a seasonal-wetland-dominated basin due to the presence of an old drainage ditch. Site 5 was a peripheral seasonal wetland of a semipermanent-wetland-dominated basin on the Coteau Prairie WPA (NW 1/4, Sec. 33, T 117 N, R 49 W) in Deuel County. Site 6 was not on a seasonal wetland per se, but located in a semipermanent wetland on the Eriksen WPA (NW 1/4, Sec. 28, T 117 N, R 49 W) in Deuel County. This site was supporting seasonal wetland plant species as a result of drawdown, a condition that frequently occurs due to drought (Stewart and Kantrud 1971). The Lake Cochran Recreation Area is owned by the S.D. Department of Game, Fish, and Parks and the WPA's are owned by the U.S. Fish and Wildlife Service.

Site 3 was on a Parnell soil surrounded by Poinsett, Buse, and Pierce soils (Westin et al. 1959) in Cary-age end moraine of the Prairie Coteau (Flint 1955). The Deuel County sites are all on Mankato-age end moraine (Flint 1955). Although a soil survey has not yet been published for Deuel County, the soils at Sites 1 and 2 have been classified as Parnell within the Barnes-Buse-Parnell association (Hubbard et al. 1988). The remaining 3 sites in Deuel County are also in the Barnes-Buse-Parnell association but are probably on Southam soils (J. B. Millar, personal communication).

The upland vegetation at Sites 1, 2, 5, and 6 were in native mixed-grass prairie. The uplands surrounding site 4 were dominated by smooth <u>bromegrass (Bromus inermis</u> Leyss.). Site 3 was situated within a native warm-season grass planting.

Methods

<u>Sample Selection</u>

The approximate boundary between the seasonal wetland and other communities at each site was marked with steel fence posts. Species lists for seasonal wetlands and other wetland types found in Stewart and Kantrud (1971) were used to make these boundary determinations. Areas within the posts were mapped with a plane table and alidade. The entire central seasonal wetlands at Sites 1, 2, and 3 were delineated (0.069 ha, 0.089 ha, and 0.1686 ha, respectively). A 0.224 ha portion of the seasonal wetland at Site 4 was used. At Site 5, an entire 0.120 ha unit of peripheral seasonal wetland was selected. The majority (0.297 ha) of the largest unit of seasonal wetland vegetation at Site 6 was used. Transects were systematically located every 5 m across each wetland approximately perpendicular to the longest axis of the wetland. Above ground standing crops were determined by manually clipping all vegetation at substrate level in 0.5 x 1.0 m quadrats located at random along the transects. Vegetation was harvested in September and October 1983. Seven to 12 quadrats were harvested from each wetland. Harvested material was separated by species and all dead vegetation grouped as litter. Due to the difficulty of classifying vegetative and senescent shoots of Carex and Eleocharis, these plants were not identified to species. Botanical nomenclature follows Great Plains Flora Association (1986). Material was placed in paper bags and air dried on wire racks in open-air sheds. Air-dry weights (to the nearest 0.1 g) were obtained prior to oven drying. Material was oven-dried to constant weight at 60°C. This temperature was used to avoid production of indigestible artifacts (Marten and Barnes 1980, Van Soest and Robertson 1980). Dried material was ground in a Wiley mill to pass a 1 mm screen.

Chemical and IVDDM Analyses

Duplicate samples of ground material were analyzed for moisture, crude protein (CP), ash, acid detergent fiber (ADF), neutral detergent fiber (NDF), and acid detergent lignin (ADL) at Station Biochemistry, S.D. State University. Detergent fibers and lignin were determined using the sequential procedure described by Van Soest and Robertson (1980). Other chemical procedures followed A.O.A.C. (1980). The commonly used factor of 6.25 was used to convert Kjeldahl-N to CP values (Boyd 1978).

In vitro dry matter digestibility (IVDDM) was estimated on duplicate samples of each vegetative component using a modified Tilley and Terry (1963) technique described by Marten and Barnes (1980). Deviations from the procedure were: (1) use of 100 ml fermentation vessels instead of the recommended 50 ml size and (2) samples were not gassed with CO_2. Samples were not gassed as some were not thoroughly wetted by the buffer resulting in floating material, which was easily blown onto vessel walls or out of the vessel altogether by the gas. Fresh rumen fluid was obtained immediately prior to each run of samples from a fistulated steer housed at the Beef Cattle and Sheep Nutrition Unit at S. D. State University. Five runs of the procedure were required to process all of the samples. Included in each run were triplicate samples of 2 alfalfa (*Medicago* sp.) standards obtained from G. C. Marten, U.S. Department of Agriculture, Agricultural Research Service, Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul. The high and low standards had IVDDM values of 73.9 and 60.0%, respectively.

Means of duplicate samples for all chemical analyses and IVDDM analyses were used to represent a sample's value. Excepting biomass, all values are reported as percent of dry matter at 100°C.

Site means of nutritional quality data for each species were calculated based on all quadrats containing analyzable samples from the stand. However, some samples from individual quadrats were too small to be analyzed. In these cases, small samples of the same species from different quadrats at the same site were combined for chemical analyses with the resulting values being treated as a single sample in the expression of the species mean for that stand. Even after combining these small samples, some were too small for complete nutritional analysis.

Results and Discussion

Species Composition

Species compositions of the biomass at all 6 sites are listed in Table 1. Sites 1, 2, and 4 were dominated by Carex atherodes (slough sedge), Site 3 by Polygonum amphibium emersum (= P. coccineum Muhl.; see Great Plains Flora Association 1986, Larson 1979, Van Bruggen 1976) with Aster hesperius (marsh aster) as a subdominant, and Site 6 by Scolochloa festucacea (whitetop) with C. atherodes as a subdominant, and Site 5 was codominated by C. atherodes and S. festucacea. After the above mentioned dominant and subdominant species, standing litter comprised the next largest component of the above-ground standing crops, ranging from 6.77 to 25.72% of the biomass at Sites 1 and 5, respectively. In no case did a subordinate species comprise more than 5.46% of the biomass, and most comprised less than 1%. In contrast with upland

Table 1. Species composition (percent of total biomass[a]) of plant stands in 6 seasonal wetlands in eastern South Dakota.

Species	Site 1(7)[b]	2(7)	3(10)	4(12)	5(12)	6(10)
Agropyron repens (L.)	0.12	-	1.04	-	-	-
Ambrosia artemisiifolia L.	-	-	1.33	-	-	-
Apocynum cannabinum L.	-	-	0.31	-	-	-
Aster hesperius A. Gray	-	-	27.05	-	-	-
Bidens vulgata Greene	-	-	0.13	-	-	-
Boltonia asteroides (L.)	-	-	0.34	-	-	-
Carex atherodes Spreng.	92.00	79.35	-	82.63	35.70	24.36
Carex spp.	0.20	0.79	5.46	-	-	-
Eleocharis spp.	0.25	0.86	2.24	-	1.07	0.33
Lycopus asper Greene	Tr[c]	0.54	-	-	-	0.05
Panicum capillare L.	-	0.01	-	-	-	Tr
Polygonum amphibium L. var. _emersum_ Michx.	0.54	1.16	44.05	-	0.37	-
Polygonum ramosissimum Michx.	-	-	0.01	-	-	-
Rumex sp.	-	-	0.01	-	-	-
Scirpus acutus Muhl.	-	-	-	-	-	0.01
Scirpus fluviatilis (Torr.)	-	-	-	-	0.50	-
Scirpus heterochaetus Chase.		-	0.96	-	-	- -
Scolochloa festucacea (Willd.) Link	0.11	-	-	-	36.64	56.47
Sparganium eurycarpum Engelm.	-	5.26	-	-	-	-
Spartina pectinata Link	-	1.70	-	0.06	-	-
Stachys palustris L. subsp. _pilosa_ (Nutt.)	-	-	0.08	-	-	-
Teucrium canadense L.	-	-	1.76	-	-	-
Typha sp.	-	-	-	-	-	0.71
Unidentified Poaceae	-	Tr	-	-	-	-
Standing litter	6.77	9.37	16.19	17.31	25.72[d]	18.06

[a]Biomass based on oven-dry weight at 60°C.
[b]Number in parentheses is number of 0.5 x 1 m quadrats harvested at each site.
[c]Tr indicates less than 0.01%.
[d]Includes _Drepanocladus_ sp.

native prairie, floristically simple communities are apparently the normal situation in glaciated prairie wetlands with seasonal water-regimes (Dix and Smeins 1967; see also data in Hadley 1970, and Smeins and Olsen 1970).

Three of the 4 species that occurred as dominant or codominant at a site were characteristic of seasonal wetland (Stewart and Kantrud 1971); the exception being A. hesperius which is an indicator of temporary wetland. The Eleocharis spp. (spikerushes) and Sparganium eurycarpum (giant burreed) are also indicators of seasonal wetland (Stewart and Kantrud 1971). Four semipermanent wetland indicator species (Stewart and Kantrud 1971) were present in minor amounts: Scirpus acutus (hardstem bulrush), S. fluviatilis (river bulrush), S. heterochaetus (slender bulrush), and Typha sp. (cattail). The minor occurrence of these species in seasonal wetlands is due to fortuitous circumstances enabling seed germination and subsequent growth. However, they will not persist in a true seasonal wetland presumably due to competition from the better adapted seasonal wetland species (Millar 1973). The remaining species were either drawdown species (Agropyron repens — quackgrass, Ambrosia artemisiifolia — common ragweed, Bidens vulgata — beggarticks, Rumex sp. — dock) or species characteristic of wetlands with a temporary water-regime (Stewart and Kantrud 1971). Occurrence of species characteristic of lesser water-regimes (eg., temporary wetland species in a seasonal wetland, or seasonal wetland species in a semipermanent wetland) is a common situation and is caused by either germination due to drawdown (the natural drying-up of the wetland) or persistence after antecedent years of below normal runoff (Stewart and Kantrud 1971, Millar 1976, van der Valk and Davis 1976).

Chemical Constituents and IVDDM of Species

Mean IVDDM values of the alfalfa standards for each run were lower than reported values and the discrepancy was greatest for the high standard (Table 2). Cause of underestimates was probably related to either use of larger than recommended fermentation vessels, cooling of the rumen fluid prior to sample inoculation, or both. The large vessels used could have caused a reduced microbial efficiency due to a possible lag-time in pressure build-up. Attempts were made to keep rumen fluid insulated, but sub-freezing air temperatures that prevailed during collection caused fluid temperatures to invariably drop below the 39°C holding temperature recommended by Marten and Barnes (1980). This may have reduced microbial populations in the fluid.

Aster hesperius, a sub-dominant at Site 3 (Table 1), had the best overall nutritional quality (Table 3). This species was still in flower, robust, and green at time of harvest. It typically flowers from August through October in South Dakota (Van Bruggen 1976) and thus may be termed a warm-season forb. A. hesperius had mean CP and IVDDM values of 11.0 and 51.3%, respectively. The high digestibility of A. hesperius (in relation to the graminoids) despite its high ADL content is probably due to lower total cell wall content (NDF; Table 3) in comparison to graminoids. This relationship between digestibility, ADL, and NDF has been found to exist between cultivated legumes and grasses (Van Soest 1982).

Table 2. Mean IVDDM (percent of dry matter at 100°C, n = 3 per run) of alfalfa standards included in each run of 1983 late-season forage samples.

Run	Low standard (%)	High standard (%)
1	58.9	68.4
2	56.4	67.1
3	54.1	68.5
4	54.0	68.3
5	57.7	68.8
Mean:	56.2 (0.9)[a]	68.2 (0.3)
Reported value:	60.0	73.9
Mean deviation from reported value:	-3.8	-5.7

[a]Standard error in parentheses.

Table 3. Mean chemical constituents and IVDDM of major species and litter found in late-season[a] standing crops in seasonal wetlands.

Site	n[c]	Dry matter: Percent of fresh weight[d]	Dry matter: Percent of air-dry weight	Percent of dry matter[b]: CP	IVDDM	Ash	NDF	ADF	Lignin
					Aster hesperius				
3	9	32.7	76.7	11.0	51.3	8.3	53.6	37.5	9.0
					Carex atherodes				
1	7	40.5	85.1	5.6	41.4	7.9	70.4	38.1	4.5
2	7	55.0	71.8	5.3	33.0	8.5	77.6	43.4	6.1
4	12	48.0	75.2	8.9	42.0	8.8	69.2	37.2	5.1
5	11	66.1	77.6	4.9	30.4	7.8	78.4	42.3	6.4
6	8	59.7	76.4	6.4	34.0	8.8	73.5	38.7	5.5
					Polygonum amphibium emersum				
1	2	30.9	86.1	15.3	38.7	8.7	58.0	48.9	11.0
2	2	72.9	73.0	8.3	25.4	6.7	72.3	54.1	20.1
3	10	37.4	62.4	5.4	17.9	5.8	65.3	48.7	14.7
5	2	67.9	74.7	7.3	16.8(1)[e]	6.7	73.6(1)	55.5(1)	22.0(1)
					Scolochloa festucacea				
5	12	73.2	81.4	5.4	17.6	9.7	82.0	47.1	8.7
6	10	62.9	80.1	5.3	25.0	9.2	77.1	43.9	7.4
					Litter				
1	7	77.4	85.4	10.3	19.8(6)	10.9	72.1	37.8	8.5
2	7	78.2	–[f]	11.0	18.1	14.1	70.2	39.3	11.2
3	10	73.3	85.4	7.6	14.3	6.3	77.5	58.3	21.5
4	12	69.3	82.1	12.0	20.9(11)	14.5	69.7	40.6	11.6
5[g]	12	66.3	78.2	10.1	25.4	17.2	64.3	40.6	11.6
6	10	74.8	82.0	7.4	23.6	12.7	74.0	41.7	8.3

[a]Collection dates were: Site 1 - 9/19, Site 2 - 10/11, Site 3 - 9/8, Site 4 - 10/5, Site 5 - 10/24, and Site 6 - 9/26.
[b]Dry matter at 100°C.
[c]Sample size.
[d]Dry matter at 60°C.
[e]Number in parentheses is sample size if different from n.
[f]Fresh weight dry matter was already in air-dry condition.
[g]Includes the aquatic moss *Drepanocladus* sp.

Carex atherodes, the dominant species at 3 sites and a major species at 2 sites (Table 1), had mean CP values ranging from 4.9 to 8.9% at Sites 5 and 4, respectively (Table 3). Variability at each site was also high; coefficients of variation at each site ranged from about 8 to 22%. Plants of this species were in varying stages of senescence at all sites, but culms and younger (inner) leaves were generally still quite green. Young shoots arising from rhizomes were present in many quadrats, but were only a few cm tall and did not contribute much to the biomass of any quadrat. Corns (1974) reported CP values of 7.0 to 8.2% in single cuttings of C. atherodes in late August and early September near Edmonton, Alberta. However, he did not report whether these percentages were on a moisture-free basis, or on a 55°C basis — the temperature used to dry his yield samples. Levels of CP are apparently much higher earlier in the growing season. Corns (1974) reported values of 11.0 to 12.0% in first cuttings in the latter half of June, and Clarke and Tisdale (1945) reported mean CP percentages of 12.3% in mid-June (leaf stage), 12.2% in early July (flowering), and 10.2% in late July (medium seed stage) in southern Alberta and Saskatchewan. Corns (1974) also found that, as for tame forages (Van Soest 1982), aftermath cuttings of C. atherodes maintained much higher CP contents than single or first cuts throughout the season.

IVDDM percentages of C. atherodes were low, ranging from 30.4 to 42.0% at Sites 5 and 4, respectively (Table 3). In vivo digestible dry matter of September-collected C. atherodes in the Northwest Territories, Canada, were reported to be 44.9% in Hereford steers during feeding trials in the summer following harvest, and 47.0% in the second winter following harvest (Hawley et al. 1981b). June collections of C. atherodes were reported to have in vivo digestibilities of dry matter in Hereford steers of 48% compared to 26% for February collections from the same area in Canada (Hawley et al. 1981a). Levels of NDF, ADF, and ADL were within ranges similar to tame grass species at comparable digestibilities (Van Soest 1982).

Scolochloa festucacea, dominant at Site 6 and codominant at Site 5 (Table 1), had low CP percentages (5.3 and 5.4%, respectively) and low IVDDM content (17.6 and 25.0%, respectively) (Table 3). Although this species was generally more senescent than C. atherodes, there was still substantial variation in degree of senescence within stands. Coefficients of variation at Sites 6 and 5, respectively, were 24.8 and 8.2% for CP, and 17.0 and 20.0% for IVDDM. Low CP values of 5.3 and 4.8% were also found by Smith (1973; reported N values were multiplied by 6.25) in September collections of S. festucacea in North Dakota. CP values of about 8.0% at flowering were reported by Clarke and Tisdale [1945; reported as Fluminea festucacea (Willd.) Hitchc.—Rydberg] and Neckles (1984) in Canada, and even higher values occur earlier in the growing season (Smith 1973, Neckles 1974). Neckles (1974) also reported much higher IVDDM values earlier in the growing season; about 50% at early flowering and higher preflowering values.

Polygonum amphibium emersum was dominant at Site 3 (Table 1) and was in advanced senescence with many abscised leaves. Mean CP at Site 3 was low (5.4%, CV = 13.0%) as was IVDDM (17.9%, CV = 13.2%) (Table 3). Like A. hesperius, P. a. emersum had higher ADL values than the graminoids at comparable digestibilities. High CP at Site 1 (15.3%;

Table 3) and relatively higher IVDDM (38.7%) were due to harvest of an earlier phenological stage at that site. High CP percentages may be normal for young plants of this species as, Korelyakova (1971) reported July collections of P. amphibium in the Ukrainian S.S.R. averaged 27.3%

Standing litter comprised variable proportions of standing crops at each site (Table 1). It was high in CP (7.4 to 12.0%) compared to the major species, but comparable in IVDDM to P. a. emersum and S. festucacea (Table 3). Most of the standing litter was comprised of totally senescent shoots that were produced during the current growing season by dominant species at a given site. However, totally senescent shoots of minor species, some previous year's standing litter of major species, and broken pieces of current year's senescent leaves of major species that separated during sample handling were also included in the litter.

Davis and van der Valk (1978) reported standing litters of Scirpus fluviatilis and Typha x glauca Godr. (large, robust, semipermanent wetland species) lost N, P, K, and Na via leaching from rainfall. Fallen litter of S. fluviatilis initially gained N, presumably due to a deficiency of that element in the plant tissue for microbial decomposition thereby necessitating that microbes extract N from the water in order to efficiently utilize the C in the litter. This initial N increase was not observed for the T. glauca litter. Although confounded by possible silt contamination, fallen litter appeared to slowly gain total ash content over time. In contrast to standing litter, fallen litter was in contact with water in the wetland. It appears that standing litter in the seasonal wetlands of this study decomposed in much the same way as fallen litter in Davis and van der Valk's study. As seasonal wetland species are shorter in stature and much less rigid than S. fluviatilis and T. glauca, their standing litter (especially the older litter) would have a higher probability of being in total contact with the water when ponding occurred earlier in the growing season. Microbes, in combination with dead epiphyton could have been responsible for the higher CP values of the litter. Hooper-Reid and Robinson (1978) found that epiphyton could yield 14 g·m^{-2} of dry matter at 17% CP by the end of a growing season in a semipermanent wetland in Manitoba. Higher ash values of litter (Table 3), compared to values of major species, may be due to precipitation of calcium carbonates caused by shifts in carbonate equilibria due to utilization of CO_2 (for photosynthesis) by epiphytes when the litter was inundated (Wetzel 1975).

Chemical constituents and IVDDM for most of the subordinate species are listed in Table 4. Although sample sizes were small for most species, these data indicate some minor species in these wetlands may be more nutritious than the dominants at these late dates in the growing season. Agropyron repens, Ambrosia artemisiifolia, Bidens vulgata, Boltonia asteroides (marsh boltonia), and Teucrium canadense (Canada germander) all had CP values of greater than 10%. Species with notably higher IVDDM values than the others were: A. artemisiifolia (50%), B. asteroides (48.4%), and T. canadense (51.3%). All 3 of the semipermanent wetland species analyzed (Scirpus fluviatilis, S. heterochaetus, and Typha sp.) had very low CP and IVDDM values (Table 4), and were almost totally senescent when harvested.

Table 4. Mean chemical constituents and IVDDM of subordinate species found in late-season[a] standing crops in seasonal wetlands.

		Dry matter		Percent of dry matter[b]					
Site	n[c]	Percent of fresh weight[d]	Percent of air-dry weight	CP	IVDDM	Ash	NDF	ADF	Lignin
				Agropyron repens					
3	2	47.3	80.9	12.2	36.0	11.3	68.0	40.7	6.7
				Ambrosia artemisiifolia					
3	2	32.3	85.9	11.2	50.6	12.0	53.3	41.4	9.7
				Apocynum cannabinum					
3	1	29.0	87.0	3.2	31.9	7.8	61.5	49.1	17.0
				Bidens vulgata					
3	1	33.3	89.5	10.8	-	9.2	51.9	39.2	9.6
				Boltonia asteroides					
3	1	27.4	86.0	13.3	48.4	8.7	45.6	35.1	9.7
				Carex spp.					
1	1	53.3	83.8	5.5	-	6.4	73.1	38.9	5.1
2	1	70.2	74.5	4.2	22.5	7.8	77.1	41.8	4.8
3	7	46.4	85.8	7.5	34.6	9.2	69.8	39.0	4.8
				Eleocharis spp.					
1	1	53.8	84.9	6.7	-	16.2	66.9	43.3	5.0
2	2	82.9	-[e]	4.2	15.6	13.1	78.4	51.1	10.0
3	5	60.0	89.4	6.0	28.5	13.2	74.4	46.5	6.6
5	3	82.2	-[e]	5.0	10.6	12.6	79.3	53.3	13.4
6	1	81.0	-[e]	5.8	31.8	13.9	65.5	41.4	6.0
				Lycopus asper					
2	1	74.2	-[e]	8.2	25.3	6.3	66.6	49.3	13.0
				Scirpus fluviatilis					
5	1	52.6	85.9	3.1	9.2	9.4	81.5	48.8	10.8
				Scirpus heterochaetus					
2	1	71.3	75.0	3.8	8.0	12.3	80.2	48.7	8.1
				Sparganium eurycarpum					
2	4	83.1	-[e]	6.3	15.8	8.7	77.8	46.0	11.9

Table 4 Cont.

Site	n[c]	Dry matter: Percent of fresh weight[d]	Dry matter: Percent of air-dry weight	Percent of dry matter[b]: CP	IVDDM	Ash	NDF	ADF	Lignin
				Spartina pectinata					
2	1	67.8	72.8	4.2	22.7	5.1	81.5	48.0	8.0
4	1	53.7	81.8	6.6	-	7.6	-	-	-
				Stachys palustris					
3	1	58.5	91.2	8.1	-	12.0	-	-	-
				Teucrium canadense					
3	3	32.6	85.2	13.7	51.3	9.6	47.2	32.6	7.0
				Typha sp.					
6	1	77.5	-[e]	2.5	14.9	4.6	79.9	48.7	12.0

[a]Collection dates were: Site 1 - 9/19, Site 2 - 10/11, Site 3 - 9/8, Site 4 - 10/5, Site 5 - 10/24, and Site 6 - 9/26.
[b]Dry matter at 100°C.
[c]Sample size.
[d]Dry matter at 60°C.
[e]Fresh weight dry matter was already in air-dry condition.

Standing Crops

Mean standing crops, including and excluding standing litter, at each site are listed in Table 5. The majority of the standing litter component appeared to be senescent current season production. Therefore, standing-crop-including-litter values should be roughly comparable to peak season standing crops. Fulton et al. (1986) summarized data from 16 sources and concluded that peak standing crops of all 3 major water-regimes of prairie wetlands occur in mid-summer. They listed "typical" values of peak standing crops for several species of seasonal wetland plants, with about 784 $g \cdot m^{-2}$ (3.5 $T \cdot acre^{-1}$) being typical peak yields for Carex atherodes and Scolochloa festucacea. All yields, including litter, reported in the present study were larger than 784 $g \cdot m^{-2}$; although the range encompassed by the yield at Site 3 minus 1 standard error includes this value. However, yields that include litter in this study also include dry matter produced during the latter part of the growing season and may be inflated estimates of mid-season standing crops reported in most other studies. As most studies do not include standing litter in their estimates, the typical early September yields listed by Fulton et al. (1986) are more comparable to the yields of this study that do not include litter (Table 5). They listed 560 $g \cdot m^{-2}$ (2.5 $T \cdot acre^{-1}$) as typical early September yields for C. atherodes, S. festucacea and mixed stands of these 2 species with P. a. emersum. Yields, excluding litter, at all 6 sites in this study exceeded these typical values by at least 112 $g \cdot m^{-2}$ (0.5 $T \cdot acre^{-}$).

Most of the studies summarized by Fulton et al. (1986) were from locations farther north in the prairie pothole region than the present

Table 5. Late-season standing crops in 6 seasonal wetlands.

		Standing crop[a]			
		Including litter[b]		Excluding litter	
Site (date)	n[c]	$g \cdot m^{-2}$ ($T \cdot acre^{-1}$)	Std. error	$g \cdot m^{-2}$ ($T \cdot acre^{-1}$)	Std. error
1 (9-19)	7	1228.9 (5.48)	91.2	1145.7 (5.11)	77.6
2 (10-11)	7	1168.7 (5.21)	138.1	1059.2 (4.73)	119.6
3 (9-8)	10	823.4 (3.67)	53.0	690.1 (3.08)	49.3
4 (10-5)	12	968.7 (4.32)	127.1	801.0 (3.57)	126.2
5 (10-24)	12	914.5 (4.08)	88.7	679.3 (3.03)	79.1
6 (9-26)	10	933.2 (4.16)	128.6	764.7 (3.41)	82.1

[a]Dry matter at 60°C.
[b]Standing litter.
[c]Sample size.

study sites. The higher yields found in South Dakota may be indicative of latitudinal production gradients. In a review of the production ecology of several species of wetland _Carex_ (none of those discussed occur to an appreciable extent in typical temporary or seasonal prairie pothole wetlands), Bernard (1973) noted a trend of decreasing production with increasing latitude. However, it should be pointed out that Fulton and Barker (1981) showed some exceptional stands of seasonal wetland vegetation in North Dakota had yields similar to those found in this study, and Smith (1973) found that peak yields of _Scolochloa festucacea_ could reach 1508 $g.m^{-2}$ (6.7 $T \cdot acre^{-1}$) on areas that had been previously burned in that state.

Forage Potential

Nitrogen requirements for ruminants depend upon energy intake (Hogan and Weston 1981, N.R.C. 1984). In turn, energy intake requirements are dependent upon body size, class, and desired level of performance. Dry, pregnant, mature cows in the middle third of pregnancy, and mature bulls on maintenance/conditioning rations have some of the lowest CP requirement of beef cattle: 6.9 to 7.1% and 6.8 to 7.8% CP (dry matter basis), respectively, depending on energy intake (NRC 1984). Of the major species in the plant stands studied, _A. hesperius_, _C. atherodes_ at Site 4, _P. a. amphibium_ at all sites where it was of minor importance, and litter at all sites had CP contents that were within the desired range, or higher, for these 2 classes of livestock. However, digestibilities of all but _A. hesperius_ (51.3%) and _C. atherodes_ (42.0%) at Site 4 were very low.

Forage quality of the bulk of these late-growing-season collections of seasonal wetland vegetation may be considered low, but late-season first cuttings of upland species are likewise low in forage quality. Late fall CP content of Bromus inermis Leyss. has been reported as 4.5% in a Saskatchewan study (Heinrichs and Carson 1956) and 6.2% in an Alberta study (Johnston and Bezeau 1962). IVDDM (dry matter at 70°C) of this species at maturity was reported as about 38% in Ontario (Pritchard et al. 1963). Moxon et al. (1951) reported state-wide average CP contents for mature Agropyron smithii Rydb. and Bouteloua gracilis (H.B.K.) Lag. ex Griffiths as 3.93 and 4.74%, respectively, in South Dakota (data reported at 12% moisture have been corrected to dry matter basis). Native upland "late-cut" hay dominated by A. smithii at Eureka and Highmore, South Dakota, averaged 5.99 and 5.29% CP, respectively, over 3 years (data reported at 10% moisture was corrected to dry matter basis) (Embry et al. 1956). Ash values reported in both of these South Dakota studies, corresponding to the above CP levels, were all similar to those found in the major species of this study. Late-cut A. smithii-dominated hay at Cottonwood, South Dakota fed to steer calves in digestion trials by Embry et al. (1956) averaged 5.6% CP (dry matter basis) and 47.96% dry matter digestibility (apparent digestibility). In a second trial, the hay averaged 3.82% CP (dry matter basis) and 41.2% digestible dry matter (apparent digestibility). Late-September collections of Andropogon scoparius Michx. and B. gracilis at Cottonwood (Kamstra 1973) had CP contents of about 2.5 and 9.5%, respectively, with corresponding IVDDM values of about 36% for both species. Mid-September collections of Stipa comata Trin. & Rupr., Carex filifolia Nutt., B. gracilis, and Calamovilfa longifolia (Hook.) Scribn. in Harding County, South Dakota, all had CP contents of less than 5.0% and IVDDM values between about 47 and 56% (Cogswell and Kamstra 1976). Early-September Panicum virgatum L. plantings at Brookings had about 5.0% CP and 41% IVDDM (Ross and Krueger 1976).

The above data show upland species, typically, are about as deficient in CP as most of the dominant wetland species found in this study at comparable dates. However, the upland species tend to be higher in digestibility at comparable CP contents.

Several of the minor species of the plant stands, such as Agropyron repens, Ambrosia artemisiifolia, Bidens vulgata, Boltonia asteroides, Lycopus asper, Stachys palustris, and Teucrium canadense, were fairly high in CP (Table 4). Species such as A. artemisiifolia, B. asteroides, and T. canadense, were also comparatively high in IVDDM. While the inclusion of these species in the biomass of these plant stands may improve the quality of hays obtained from late-growing season harvested seasonal wetlands, they would only do so if present in large quantities. In the plant stands used in this study, their occurrence in the biomass was minor (Table 1).

Chemical and IVDDM analyses showed that (for the most part) the biomass of these seasonal wetlands produced low quality forage at the end of the growing season, but biomass produced was high in comparison to upland cool-season grasses in this area. Hay yields of several varieties of Bromus inermis averaged over several years (one harvest per year) at Brookings, South Dakota ranged from 466.2 $g \cdot m^{-2}$ (2.08 $T \cdot acre^{-1}$) to 730.7 $g \cdot m^{-2}$ (3.26 $T \cdot acre^{-1}$) (Ross and Krueger 1976). All of the air-dry standing crops found in the present study were greater than those values, with some being over twice as high (Table 6). Mid-October yields of Panicum virgatum varieties at Brookings (Ross and Krueger 1976; Table 18), however, were more comparable to those found in seasonal wetlands. Dry matter yields of 582.7 $g \cdot m^{-2}$ (2.60 $T \cdot acre^{-1}$) to 927.9 $g \cdot m^{-2}$ (4.14 $T \cdot acre^{-1}$) were reported (single harvest in 1974). The upper value for P. virgatum is comparable to the lower dry matter yields of the seasonal wetlands with litter included and to the upper values without litter (Table 5).

Conclusions

In general, the forage quality of the biomass produced in the seasonal wetlands studied is poor at the end of the growing season -- being about equally deficient in CP as upland species and lower in digestibility. However, yields of biomass are high compared to most upland stands, and indicate that if harvested earlier in the growing season these wetlands may be capable of producing large quantities of acceptable forage. The standing crop data collected in this study also suggest that seasonal wetlands in South Dakota may be more productive than those found at more northerly latitudes.

Table 6. Air-dry standing crops, including litter, in 6 seasonal wetlands.

Site (date)	n[a]	Air-dry standing crop $g \cdot m^{-2}$ ($T \cdot acre^{-1}$)	Std. error
1 (9-19)	7	1443.7 (6.44)	106.5
2 (10-11)	7	1609.6 (7.18)	188.1
3 (9-8)	10	1184.7 (5.29)	80.1
4 (10-5)	12	1266.1 (5.65)	167.8
5 (10-24)	12	1167.4 (5.21)	122.6
6 (9-26)	10	1169.4 (5.22)	151.1

[a]Sample size.

Chapter 3

CHANGES IN CHEMICAL CONSTITUENTS, IVDDM, AND TNC WITH DEVELOPMENT OF FOUR SEASONAL WETLAND SPECIES

Introduction

The grass Scolochloa festucacea (Willd.) Link (whitetop), the sedge Carex atherodes Spreng. (slough sedge), and the forbs Sparganium eurycarpum Engelm. (burreed) and Polygonum amphibium L. var. emersum Michx. (smartweed) are common dominant species in seasonal wetlands of the Prairie Pothole Region (Stewart and Kantrud 1971, Van Bruggen 1976, Larson 1979). Stands of these species can yield high standing crops (Chapter 2), but produce forage of low quality if harvested late in the growing season.

Some "point-in-time" data are available for chemical constituents, apparent digestibilities, and in vivo digestibilities for slough sedge from the Northwest Territories (Hawley et al. 1981a, 1981b). Proximate analysis data are available for this species at selected phenological stages in Clarke and Tisdale (1945), Johnston and Bezeau (1962), and Corns (1974) in Saskatchewan and Alberta and for an unspecified point-in-time in British Columbia (McLean and Tisdale 1960).

Smith (1973a) presented data for whitetop on N and some other elements for numerous post-flowering stands as well as seasonal trends for selected stands in North Dakota. Clarke and Tisdale (1945) presented proximate analysis data for 2 phenological stages of whitetop [reported as Fluminea festucacea (Willd.) Hitchc.-Rydberg] from southern prairie Canada. Concurrent data on crude protein (CP) and in vitro digestible dry matter (IVDDM) in relation to date and phenology in the Delta marsh of Manitoba were collected by Neckles (1984) (see also Neckles et al. 1985). Apparent digestibility (sheep) of 7 July collected whitetop in North Dakota was reported by Christensen et al. (1947).

Very few data are available for burreed and smartweed. Korelyakova (1971) presented data for a single point-in-time measurement of CP and ash for smartweed in the Ukrainian S.S.R. Linn et al. (1975) presented proximate and detergent fiber data for burreed (collected in late-summer) from Minnesota.

Information on seasonal trends in rhizome total nonstructural carbohydrate (TNC) content for these 4 species is not available. None-the-less, some management recommendations have been made for whitetop (Looman 1983, Neckles et al. 1985) and slough sedge (Corns 1974, Looman 1983).

The collection of concurrent measurements of CP, IVDDM, and below-ground TNC in relation to phenology in whitetop, slough sedge, burreed, and smartweed in South Dakota would provide information useful in the development of management recommendations for these species in this state. In addition, concurrent detergent fiber analyses would be desirable since fiber fractions usually can be correlated, at least, with some expression of digestibility for a given species (see Van Soest 1982). In fact, acid detergent fiber and neutral detergent fiber values have been proposed for use in predictive equations designed to respectively estimate digestibility and dry matter intake of domesticated forages (Rohweder et al. 1983, Martin 1985). Silica has also been found to have an influence on digestibility in some species of plants that can accumulate it (see Van Soest 1982).

The objectives of this study were to (1) obtain data on CP, ash, detergent fiber fractions, and IVDDM in relation to phenology for whitetop, slough sedge, smartweed, and burreed from eastern South Dakota wetlands, (2) investigate use of these various chemical entities as predictors, or at least indicies, of digestibility, and (3) obtain concurrent below-ground TNC content data. Additionally, the silica content will be measured at selected points in time during the growing season in order that its influence on the nutritional quality of these species may at least be crudely assessed.

Methods

Sample Collections

Sites used for collections of whitetop, slough sedge, and burreed were within 2 of the same wetlands used for the late-season standing crop study (Chapter 2). Whitetop was collected from Site 6 and slough sedge and burreed from Site 4. Smartweed collections were taken from a small seasonal-wetland-dominated basin a few hundred meters to the west of Site 6 in 1984, and from a different small seasonal-wetland-dominated basin less than 100 m south of Site 6 in 1985.

Plants were subjectively clipped at substrate level for chemical constituent and IVDDM analyses. Plants were harvested according to the observer's opinion of what was representative of the stand. Collections began on 24 May in 1984 and repeated at intervals of less than 1 week through 11 June. Thereafter, intervals of about 1 week were used through 13 August followed by intervals of greater than 1 week until sampling terminated on 23 October. In 1985, samples were collected in the same manner as in 1984, except that sampling began on 2 May and continued approximately weekly through 29 July. Due to late growth initiation in 1985, smartweed collections began on 14 June and continued through 10 August. Notes on site conditions and plant phenology were taken on each date. In addition to these, 7 slough sedge, 3 whitetop, 4 burreed, and 5 smartweed collections were made at various other locations in Deuel County for use in testing IVDDM predictive equations developed based on 1984 data (see below).

After clipping, each collection was placed in a plastic bag and transported to the lab where approximate fresh weights were obtained. Samples were then placed in paper bags and dried on suspended wire racks in open-air, covered sheds. Air-dried material was weighed and dried to constant weight in forced-air ovens at 60^{o}C. Oven-dried material was ground in a Wiley mill to pass a 1 mm screen and stored in sealed glass jars after thorough stirring.

Rhizome samples of each species were collected within the same stands used for shoot collections, and were obtained on the same dates as shoot samples in both years. However, a few rhizome collections in 1985 were made early in the growing season prior to shoot growth. Chunks of sod at least 28 dm^3 in size (ca. 1 ft^3) were dug with a spade for whitetop, slough sedge, and burreed. Smartweed rhizomes, being large and infrequent even in dense stands, were collected by excavating several individual rhizomes. As much shoot material as possible was allowed to remain intact during all collections. Samples were pre-washed in the field and transported to the lab in large plastic bags.

At the lab, remaining soil was removed from plant material by hand manipulation in tap water. Roots were removed from the rhizomes. Washed plants were separated into below- and above-ground portions disregarding morphological positions.

Notes were taken of observed phenological events during preparation of below-ground material. For future reference in this paper, an arbitrary distinction was made between "tillering" and "new shoot" production. Tillers will be defined as new shoots produced at nodes above and also below the substrate from rhizomes that elongated for no more than a few cm before turning up and terminating in a new aerial shoot. "New shoots" will be defined as shoots from new rhizomes that elongated for several cm or more away from the parent shoot or rhizome. Thus, tillers are essentially new shoots, but arise in very close proximity to the parent shoot.

Measurements at study sites indicated the juncture of shoot and crown (the crown being a series of very short and compact rhizomes between tillers) in slough sedge and shoot and corm in burreed occurred, on average, about 10 cm below the substrate surface. Therefore, for these two species the lowest 10 cm of the shoots were included in the below-ground fraction. Whitetop can produce rhizomes and tillers from nodes at varying levels beneath and above the substrate, and does so profusely. In addition, roots occur not only on below-ground internodes, but also on above-ground internodes below the water surface. The only reliable indicator for making a separation between below-ground and above-ground portions was color. Below-ground material was white, while green pigmentation began at the substrate surface. This approximate change in color was used to separate above- from below-ground material. Color change was also used to separate above- from below-ground portions in smartweed. Smartweed not only branches or produces roots at any node both above and below ground like whitetop, but also has no external structural differentiation between above- or below-ground stems. Younger stems had pink coloration below and a red-green pigmentation above the substrate. The below-ground portion of older stems had a much thicker and tougher epidermis and was usually dark red-brown or blackish in color. Plants were separated into above- and below-ground portions, cut into small pieces (ca. 1 to 2 cm), dried at 100°C for 90 min followed by 70°C until samples reached constant weight (Smith 1981), ground in a Wiley mill to pass a 1 mm screen, placed in covered glass jars, and stored in a desiccator.

Laboratory Procedures and Chemical Analyses

Shoot samples collected in 1984 were analyzed for crude protein (CP), ash, neutral detergent fiber (NDF), acid detergent fiber with NDF pre-extraction (ADF1), acid detergent fiber without NDF pre-extraction (ADF2), acid detergent lignin (ADL), and IVDDM (see Methods section, Chapter 2). Shoot samples collected in 1985 were analyzed for CP, ash, and IVDDM. However, other chemical constituents analyzed for on 1985 shoot samples were different for each species. Results of the multiple regression analyses (see below) of 1984 data were used to select those constituents for analysis for each species. Silica analyses (procedure of Van Soest and Wine 1968) were conducted on 3 species for 5 sampling dates and for 3 sampling dates on smartweed.

TNC content was measured on both above- and below-ground material in 1984 but only on below-ground material in 1985. TNC analyses were conducted by Station Biochemistry using procedures of Smith (1981) that utilize enzymatic hydrolysis of sucrose and starch but an acid hydrolysis of fructosans following enzymatic hydrolysis. In order to keep analytical expenses down, 3 rhizome samples of each species were collected on 21 November 1983 and subjected to both types of hydrolysis to determine which needed acid treatment. The 1983 slough sedge samples were obtained from the same stand used for 1984 and 1985 collections; however, the other 3 species' samples were obtained from wetlands on the Brookings Waterfowl Production Area (NW 1/4, Sec. 16, T111N, R52W) in Brookings County.

Prediction Equations for Digestibility

IVDDM and chemical constituent data collected for each species in 1984 were used to construct multiple regression equations that might be used to predict digestibility. SAS (1985) statistical procedures were used in the screening of independent variables (chemical constituents). IVDDM was first regressed against each independent variable in separate linear analyses. The residuals were plotted against the predicted IVDDM (Draper and Smith 1981) and inspected for patterns suggesting polynomial relationships. Only if addition of a squared, or squared and cubed terms, produced a significant ($P < 0.05$) increase in the R^2 value was the polynomial considered for inclusion in multiple regression analyses. Tests of collinearity (Belsley et al. 1980) were performed on the multiple regressions using all independent variables (no polynomial terms included) prior to performing multiple regressions with all variables that produced significant ($P < 0.05$) linear or polynomial regressions. Variables found to be collinear were not included together in the same multiple regression. There is a certain amount of subjectivity in the selection of cut-off values for regression diagnostics in the determination of collinearity (Vinod and Ullah 1981, Dillon and Goldstein 1984). Therefore, a conservative variance decomposition value of 0.50, or greater, for 2 or more variables associated with a condition index of 30, or greater, was used (Dillon and Goldstein 1984). In determining a final "best" equation, only those variables that produced a significant ($P < 0.05$) increase in the R^2 value were considered. Both stepwise forward methods and all possible regressions were used to inspect equations.

Variables found to be the best potential predictors of IVDDM for each species were used as the basis for selection of chemical analyses to be performed on the 1985 collections, both those samples repetitively collected from the same stands and the additional collections of each species (see above). A qualitative test of the predictive ability of the equations was made by comparing the predicted IVDDM of each of the 1984 samples with the measured IVDDM.

Results and Discussion

Chemical Constituents and IVDDM

Alfalfa Standards

Mean IVDDM values for the alfalfa standards for each run of the procedure are listed in Table 7. Over all runs, the low standard averaged 3.1 points lower and the high standard averaged 5.6 points

Table 7. Mean IVDDM (percent of dry matter at 100°C, n =3 per run) of alfalfa standards included in each run of 1984 and 1985 whitetop, slough sedge, burreed, and smartweed samples.

Run	Low standard (%)	High standard (%)
1[a]	59.0	68.3
2[a]	57.9	69.9
3[b]	58.4	69.9
4[c]	54.5	67.0
5[d]	54.7	66.0
Mean:	56.9 (0.9)[e]	68.3 (0.7)
Reported value:	60.0	73.9
Mean deviation from reported value:	-3.1	-5.6

[a]Contained 1984 whitetop, slough sedge, burreed, and smartweed samples.
[b]Contained 1985 whitetop, slough sedge, burreed and smartweed samples.
[c]Contained 1985 additional collections on whitetop, slough sedge, burreed, and smartweed samples.
[d]Contained re-runs of some samples.
[e]Standard error in parentheses.

lower than the reported values. Causes of the low IVDDM estimates are discussed in Chapter 2.

Whitetop

CP contents of whitetop sampled from the same wetland in 1984 and 1985 are presented in Figure 1. Dates for observable phenological events are listed in the footnotes of Tables 8 and 9. Like phenological events occurred several days earlier in 1985 than in 1984 due to warmer spring temperatures. The plants began the growing season with high CP percentages typical of most grasses; although CP content was higher in May collected plants in 1984. At jointing to boot stages (late May to early June), CP had dropped to 11.3% in 1984 and 12.5% in 1985. At anthesis, CP was 8.6% in 1984 and 9.9% in 1985 (mid June). At seed fill (mid to late June) in both years, CP was just below 8%. Except for a secondary peak on 2 July 1984 due to a large number of new shoots and tillers in the sample, CP content dropped to between 5 and 6% for the remainder of the growing season until October when 1984 data show it dropped to between 3 and 4%. CP values of the whitetop sampled in this study were similar to those reported by Clarke and Tisdale (1945) from southern Alberta and Saskatchewan, by Neckles (1984) from Manitoba, and by Smith (1973a) from North Dakota for like phenological stages.

Percentages of IVDDM for whitetop in both years are presented in Figure 2. The highest value for the 1984 collections (60%) occurred on the first sample date (24 May) while in 1985 it occurred on 13 May (54.4%). By early June in 1984 and late May in 1985, IVDDM dropped below 50%. At anthesis, IVDDM was 34.5% in 1984 (18 June) and 40.2% in 1985 (14 June). After anthesis, IVDDM fluctuated in the 32 to 45% range

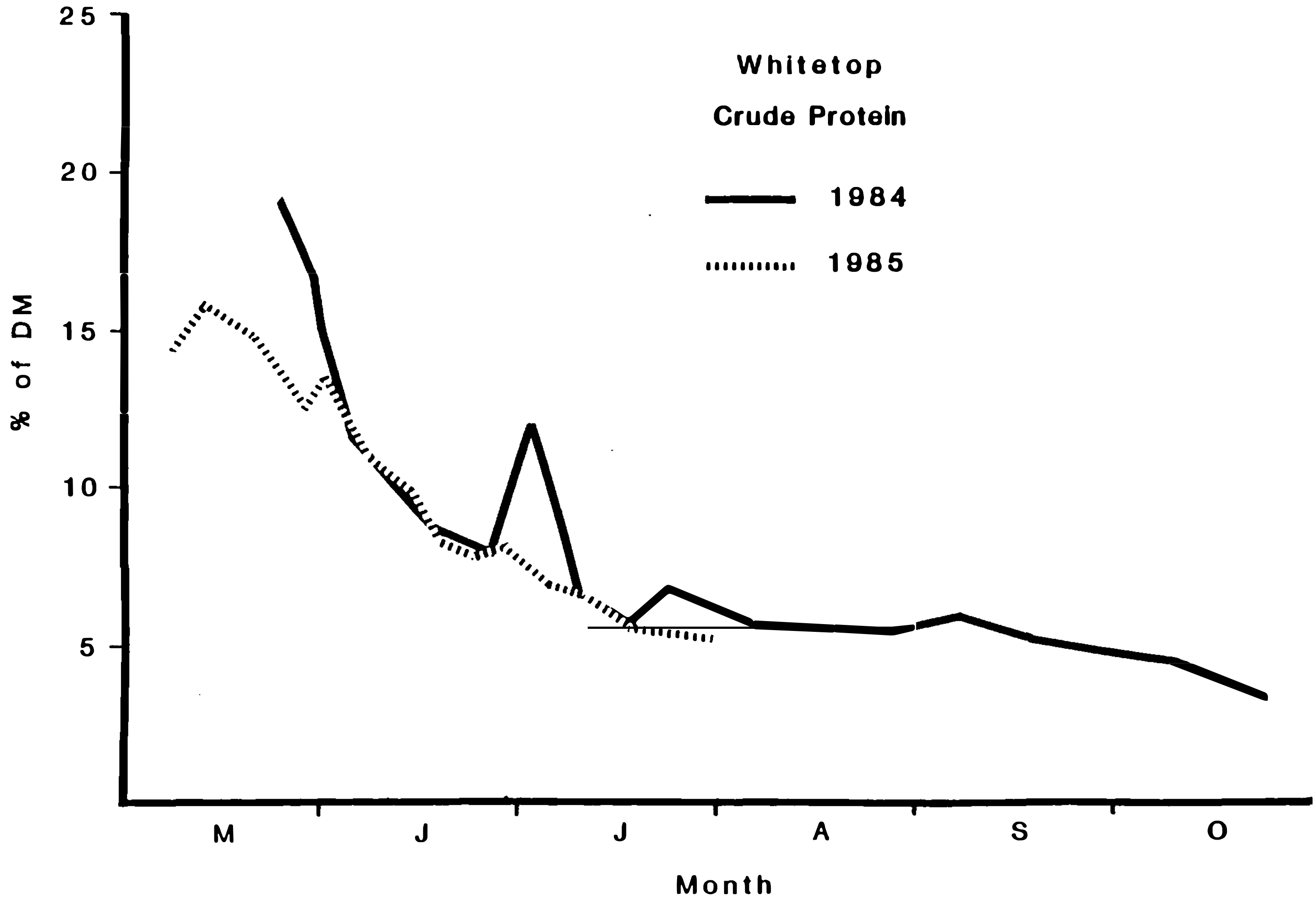

Figure 1. CP content (% of dry matter) of whitetop shoots collected in 1984 and 1985.

Table 8. Chemical constituents of whitetop shoots collected from a single stand in 1984 (n = 1 for each line).

	Percent moisture[a]		Percent of dry matter[b]				
Date	Fresh	Air-dry	Ash	NDF	ADF1[c]	ADF2[d]	ADL
5-24	81.3	25.9	8.35	67.6	31.2	32.9	2.84
5-29	78.8	20.5	7.97	66.6	30.9	33.1	2.78
5-31[e]	78.5	12.0	8.27	74.6	34.1	36.2	3.27
6-05	76.7	9.9	7.75	77.6	37.1	41.1	4.36
6-07[f]	77.0	19.6	7.67	79.9	39.0	40.7	4.45
6-11[g]	78.6	7.9	7.30	82.0	41.6	44.5	4.86
6-18[h]	76.5	13.4	6.24	81.3	42.8	43.8	6.43
6-26[i]	67.3	15.4	5.27	81.5	44.6	46.6	6.78
7-02[j]	68.1	11.2	5.20	77.7	41.9	42.5	6.98
7-09[k]	62.8	10.2	4.47	71.9	38.3	40.4	6.30
7-16[l]	61.9	12.2	4.59	68.8	37.1	38.0	6.86
7-23	62.3	12.8	4.64	68.8	35.4	36.8	6.23
7-30	58.5	8.6	4.85	67.1	34.3	37.2	6.20
8-06	59.7	8.5	4.74	67.0	35.3	36.7	5.87
8-13	54.0	13.4	5.01	65.3	34.4	35.8	6.08
8-27	45.5	8.6	5.09	63.9	33.8	35.7	6.59
9-07	55.1	16.7	5.96	65.7	34.2	37.7	5.89
9-18	41.6	13.4	5.83	68.4	36.2	38.7	6.41
10-09	71.2	13.6	6.65	81.2	45.0	49.1	7.64
10-23	57.8	10.9	5.56	83.2	46.7	50.5	8.16

[a] Approximate; based on dry matter at 60°C.
[b] Dry matter at 100°C.
[c] ADF1 = ADF after extraction for NDF.
[d] ADF2 = ADF without pre-extraction for NDF.
[e] Tillering began.
[f] Jointing began. Boot stage evident on earliest of flowering shoots.
[g] New rhizome elongation began.
[h] Anthesis.
[i] Seed fill.
[j] Abundant new shoots/tillers.
[k] Senescence began.
[l] Seed drop and half of material sensecent.

Table 9. Chemical constituents of whitetop shoots collected in 1985 (n = 1 for each line).

	Percent moisture[a]		Percent of dry matter[b]		
Date	Fresh	Air-dry	Ash	ADF2[c]	Silica
		Single stand collections			
5-08[d]	93.4	18.7	9.92	31.9	—
5-13	90.1	18.7	9.75	33.8	1.83
5-20	90.0	16.4	8.90	35.9	—
5-28[e]	85.9	21.4	9.00	41.1	2.50
6-01[f]	84.9	20.2	9.41	40.1	—
6-07	82.9	19.7	9.16	42.3	—
6-14[g]	82.4	18.5	8.10	41.0	2.93
6-19[h]	77.7	16.5	7.31	41.2	—
6-24[i]	73.6	16.2	7.74	37.4	—
6-28	75.7	15.5	7.76	41.5	—
7-05	73.3	15.1	6.41	36.9	2.45
7-10[j]	71.2	16.6	7.83	38.8	—
7-18	68.4	15.2	6.59	37.8	—
7-29	63.0	15.2	6.66	38.4	3.45
		Additional stand collections			
7-10	59.1	13.6	9.23	45.8	—
7-29	54.9	13.3	7.19	39.4	—
8-09	57.2	14.5	6.90	41.7	—

[a]Approximate; based on dry matter at 60°c.
[b]Dry matter at 100°c.
[c]ADF2 = ADF without pre-extraction for NDF.
[d]Most shoots not yet emerged from water surface.
[e]Jointing/boot stage.
[f]Tillering began.
[g]Anthesis.
[h]New rhizome elongation.
[i]Seed fill.
[j]Seed drop; senescence began on upper leaf tips.

Figure 2. IVDDM (% of dry matter) of whitetop shoots collected in 1984 and 1985.

for the remainder of the summer. The 1984 data show that IVDDM began a steady decline in early September until it reached 16.6% on 23 October -- the last collection date.

Neckles (1984) reported higher IVDDM values for whitetop from the Delta Marsh in Manitoba than those found in this study at comparable phenological stages. For example, at boot stage she reported an IVDDM of about 56%. In the present study, the boot stage collection of 1984 had an IVDDM of 39.3% while that of 1985 was 42.7%. Thus, the mean of the 2-years' boot stage collections (41%) was 15 percentage points lower than found in Manitoba. Mean IVDDM of both years' collections at anthesis (37.4%) was about 10 points lower than that reported by Neckles (1984) at anthesis. This discrepancy in IVDDM between Manitoba- and South Dakota-collected whitetop can only be partially accounted for on the basis of the somewhat low efficiencies of the IVDDM assays (Table 7). The remaining discrepancy may possibly be explained by the northern population operating on more of a "carbohydrate economy" than southern plants. McNaughton (1966) found that in cattail (<u>Typha latifolia</u>) collected from North Dakota and Texas, and grown under controlled environments, the northern ecotype had higher nonstructural carbohydrate contents and lower protein to nonstructural carbohydrate ratios than the southern ecotype. This difference in the carbohydrate economy of the ecotypes was believed to be due to the need for the northern plants to be able to convert proportionately more incoming radiation to storage forms of energy to prepare the plants for winter in the face of a short growing season.

The ADF and ADL values of the 1984 whitetop samples were all within ranges characteristic of temperate grasses (Table 8), but NDF values were somewhat higher (N.R.C. 1982, Van Soest 1982). ADF2 was always higher than ADF1; the difference ranging from about 0.5 to 4 units. This difference is a crude estimate of pectins, tannins, and silica combined (Van Soest and Robertson 1980). Silica analyses were made on selected samples from 1985 and ranged from 1.83 (13 May) to 3.45% (29 July) (Table 9). Thus, silica probably accounts for most all of the discrepancy between ADF1 and ADF2. Silica, however, is not totally accounted for by difference of the ADF's; some may not be solubilized in neutral detergent (Van Soest and Robertson 1980). The ash values for both years (Tables 8 and 9) are similar to many domesticated forage grasses (N.R.C. 1982). Decline in ash over the growing season was probably due to leaching of ions from the senescing plant material (Davis and van der Valk 1978). This species began senescence by mid-summer and, although numerous small young shoots were present in late summer, the bulk of vegetation was straw-colored. The slight increase in ash toward the end of the growing season could be due to the contribution from the small green shoots and/or concentration in dead material by microbial decomposition of organic matter.

Moisture contents of fresh and air-dry material are also listed in Tables 8 and 9. Fresh moisture percentages are probably low estimates due to several hours lag time between collection and weighing. The generally declining moisture content of whitetop over the growing season reflects declining transpirational activity of the plants (Eisenlohr 1966, 1969). The high moisture values, especially early in the season when nutritive quality is also high, would limit dry matter intake by grazing animals. The air-dry moisture values are only roughly representative of moisture levels one might expect in hay produced from this species, as small loose samples in paper bags should be more subject to variations in atmospheric humidity than bales after sun curing. Nonetheless, most values were below 20% (the upper limit suggested by Rohweder et al. 1981 for hay), and many 1984 samples were less than 15% (the upper limit suggested by Van Soest 1982 for proper hay storage).

Slough Sedge

Except for one date, slough sedge was consistently higher in CP (Figure 3) than whitetop. As for most species of plants, CP levels were highest early in the growing season (20.1% in 1984 and 17.7% in 1985). The peak in CP in 1985 occurred on the third collection date (13 May). The depressed CP content on the first and second collection dates were probably due to depressed photosynthesis as most shoots were still submerged. The enzyme ribulosebisphosphate carboxylase of the photosynthetic system comprises 15% of the enzymes (and hence protein) of the chloroplasts (Lehninger 1975).

CP content dropped to 14.6% at anthesis in 1984 (6 June) and 15.1% at anthesis in 1985 (28 May; dates of key phenological events are listed in Tables 10 and 11). When the achenes began to fill, CP had dropped to 13.6% in 1984 (18 June) and 12.9% in 1985 (7 June). CP dropped below 10% in late June in 1985 and early July in 1984. Fluctuations between about 7 and 9% occurred throughout the remainder of the collection periods.

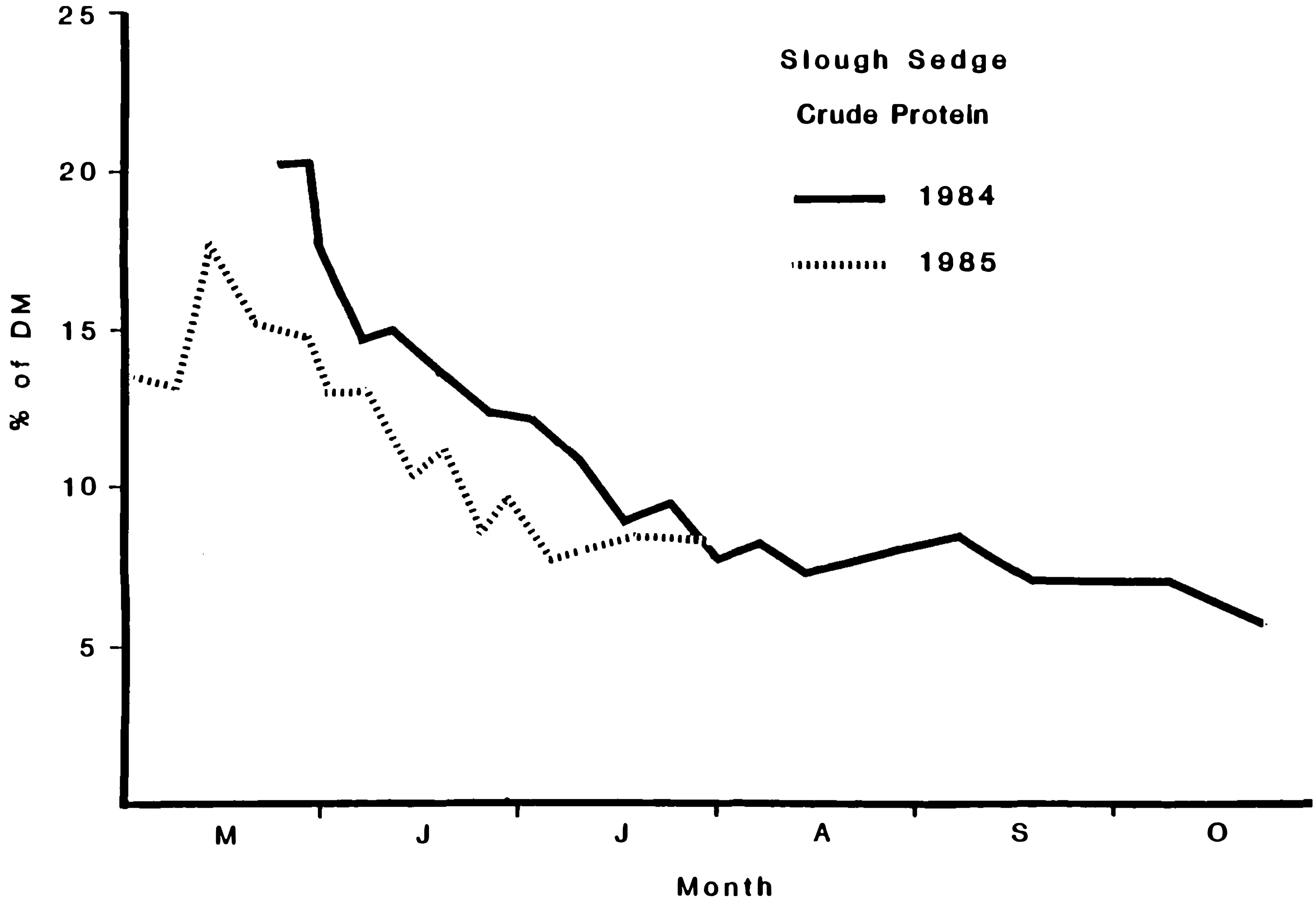

Figure 3. CP content (% of dry matter) of slough sedge shoots collected in 1984 and 1985.

Table 10. Chemical constituents of slough sedge shoots collected from a single stand in 1984 (n = 1 for each line).

	Percent moisture[a]		Percent of dry matter[b]				
Date	Fresh	Air-dry	Ash	NDF	ADF1[c]	ADF2[d]	ADL
5-24	83.0	49.4	9.32	65.8	29.7	32.2	3.45
5-29	81.5	37.4	8.69	64.4	29.3	31.8	2.60
5-31	81.6	11.3	9.31	69.7	31.1	36.2	4.09
6-05[e]	81.1	9.8	8.63	72.1	34.5	37.9	3.72
6-07[f]	82.6	20.8	8.82	73.1	34.7	37.3	4.31
6-11[g]	84.6	8.8	8.06	72.1	34.0	36.4	3.80
6-18[h]	84.6	15.1	7.81	72.9	35.3	37.3	3.28
6-26	78.6	15.0	7.85	73.9	37.0	40.3	4.16
7-02	77.3	9.5	7.69	73.7	35.7	38.7	4.26
7-09	77.2	10.9	8.24	73.5	36.9	40.0	4.28
7-16	73.8	13.7	7.32	73.3	36.8	40.6	4.35
7-23[i]	67.5	12.8	7.58	73.7	36.0	39.6	4.21
7-30	70.3	9.2	7.87	73.5	37.1	39.7	4.49
8-06	71.7	8.8	7.43	74.7	38.8	42.0	4.48
8-13	64.8	13.7	7.22	74.2	37.2	39.8	4.74
8-27	59.5	8.8	7.81	72.3	36.7	39.4	4.75
9-07	71.1	18.3	8.12	70.5	37.6	39.8	4.51
9-18	50.3	12.6	7.51	70.6	37.3	40.2	4.48
10-09	76.3	14.2	8.96	76.1	40.4	45.3	5.22
10-23[j]	60.9	12.0	8.82	74.7	39.4	45.5	5.43

[a]Approximate; based on dry matter at 60°C.
[b]Dry matter at 100°C.
[c]ADF1 = ADF after extraction for NDF.
[d]ADF2 = ADF without pre-extraction for NDF.
[e]Tillering began (2nd cohort of shoots).
[f]Anthesis began.
[g]New rhizome elongation.
[h]Seed fill.
[i]Flowering shoots senescing
[j]About one-third of shoots senescent.

Table 11. Chemical constituents of slough sedge shoots collected in 1985 (n = 1 for each line).

	Percent moisture[a]		Percent of dry matter[b]	
Date	Fresh	Air-dry	Ash	Silica
		Single stand collections		
5-02	87.2	18.8	6.48	—
5-08	88.1	18.5	8.21	0.73
5-13	85.9	17.3	8.50	—
5-20	85.7	21.1	9.60	—
5-28[c]	81.9	21.2	9.41	2.13
6-01[d]	79.9	18.7	9.09	—
6-07[e]	79.3	19.3	9.01	—
6-14	76.3	18.6	7.74	2.02
6-19	76.1	15.9	8.82	—
6-24[f]	71.7	15.8	7.35	—
6-28	71.7	15.6	7.83	—
7-05	60.3	15.3	7.30	2.50
7-10[g]	62.9	14.2	8.00	—
7-18	67.0	15.8	8.54	—
7-29	62.6	15.6	7.93	2.91
		Additional stand collections		
6-28	73.1	16.1	7.33	—
7-24	65.4	15.2	6.22	—
7-24	68.3	14.9	8.94	—
7-29	61.5	15.3	7.27	—
7-29	62.3	15.3	6.67	—
8-09	68.9	14.9	10.30	—
8-09	73.6	15.3	9.40	—

[a]Approximate; based on dry matter at 60°C.
[b]Dry matter at 100°C.
[c]Anthesis.
[d]"Tillering" began (2nd cohort of shoots).
[e]Seed fill.
[f]New rhizome elongation.
[g]Seed shattered.

The CP data for slough sedge plants collected in this study compare well with those of Clarke and Tisdale (1945) and Corns (1974; for his first cut dates) in Canada at comparable growth stages or dates. However, data from southwest Alberta showed lower CP percentages by several points (Johnston and Bezeau 1962).

IVDDM values for slough sedge were highest on 29 May in 1984 (68.6%) and on 13 May in 1985 (63.3%) (Figure 4). At anthesis, IVDDM had dropped to 61.5% in 1984 (7 June) and 58.5% in 1985 (28 May). In early July of both years, IVDDM dropped and stayed below 50% for the remainder of the growing season. Through July in both years, IVDDM stayed above 40%. Except for a low value of 37.7% on 13 August, it continued to remain above 40% in 1984 until mid-September and reached a low of 33.3% on 23 October.

The in vivo digestible dry matter (in vivo DDM) values reported for June- and February-collected slough sedge in the Northwest Territories were 48 and 26%, respectively, for Hereford cattle (Hawley et al. 1981a). September-harvested slough hay (95% slough sedge) from the same region had an in vivo DDM of 47% the following winter in Herefords (Hawley et al. 1981b). The values reported by these authors compare well with the IVDDM values reported in the present study.

Ash values of slough sedge in both years were similar (Tables 10 and 11) and did not show a pronounced decline as in whitetop (Tables 8 and 9). Senescence occurred slowly in the slough sedge stand and much green material was still present by late October. The ash content throughout the season of this species was similar to the early season values for whitetop. The values of the detergent fibers and lignin of

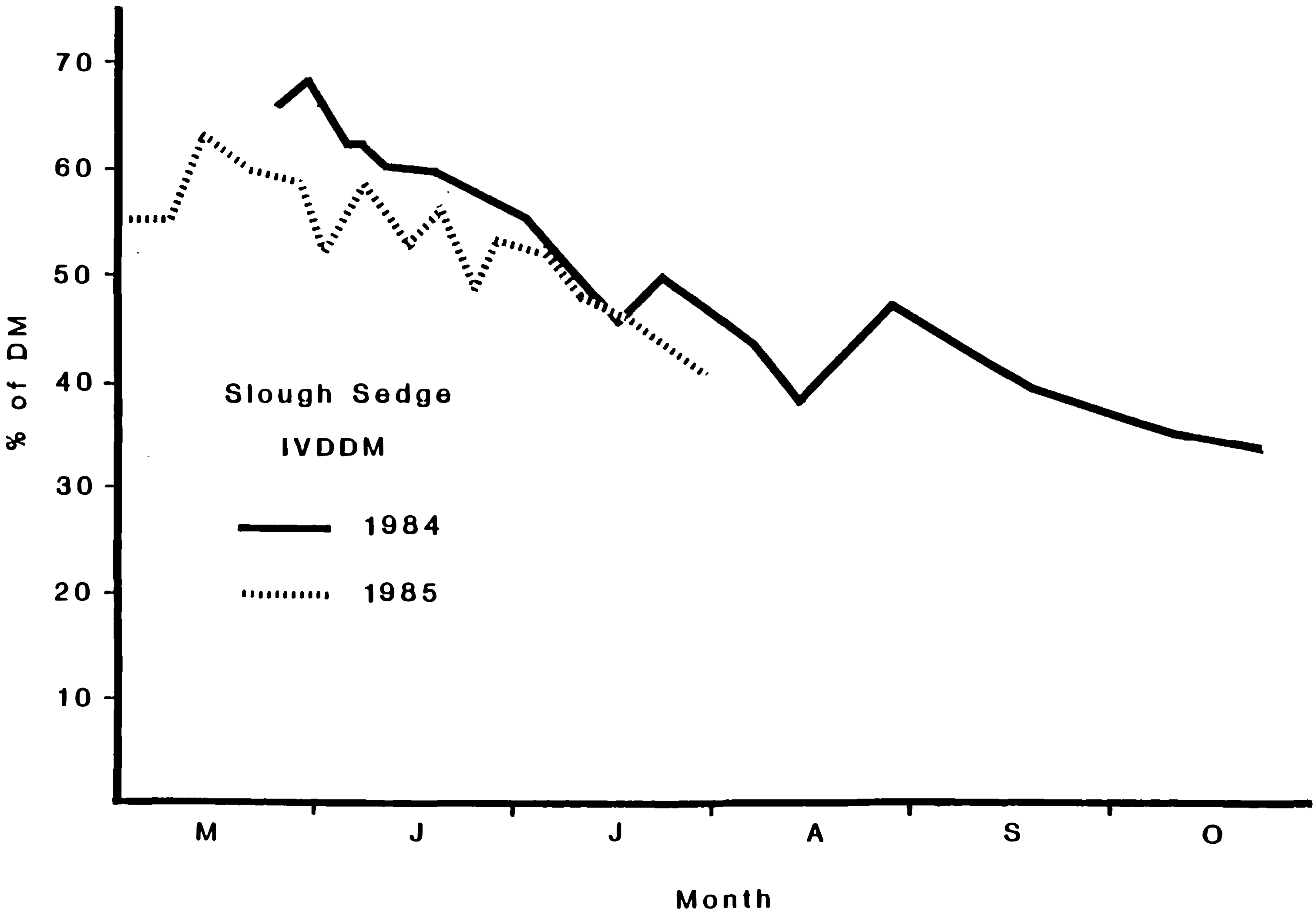

Figure 4. IVDDM (% of dry matter) of slough sedge shoots collected in 1984 and 1985.

slough sedge were generally lower than those for whitetop. Lower fiber and higher CP values were no doubt responsible for the generally higher IVDDM values of this species as compared to whitetop. As in whitetop, the bulk of the difference between ADF1 and ADF2 in slough sedge (Table 10) was probably accounted for by silica (Table 11). Moisture values of both fresh and air-dry slough sedge (Tables 10 and 11) were similar to whitetop (Tables 8 and 9).

Burreed

The CP content of burreed at the onset of the growing season in both years was about 20% (Figure 5). The decline in CP content in 1984 leveled off in early July and remained between about 8 and 10% until near the end of the growing season. The same trend happened in 1985 (only it started earlier by calendar date), but sampling was terminated sooner in that year. Anthesis occurred over a long time, lasting from 11 June to 30 July in 1984 and from 14 June to 18 July in 1985. Duration of flowering may last about a week on an individual shoot, but different shoots within the stand flowered throughout the above time spans. As a result, CP content ranged widely in the stand during anthesis. The CP value of 7.6% listed by Linn et al. (1975) for this species in Minnesota collected in late summer agrees closely with the late summer values found in this study during 1984.

Burreed IVDDM (Figure 6) was highest on 24 May in 1984 (65.2%) and on 13 May in 1985 (61.4%). IVDDM dropped steadily in both years to anthesis initiation (40.3% in 1984 and 35.5% in 1985) and continued to do so until anthesis termination (24.6% in 1984 and 18.0% in 1985). The

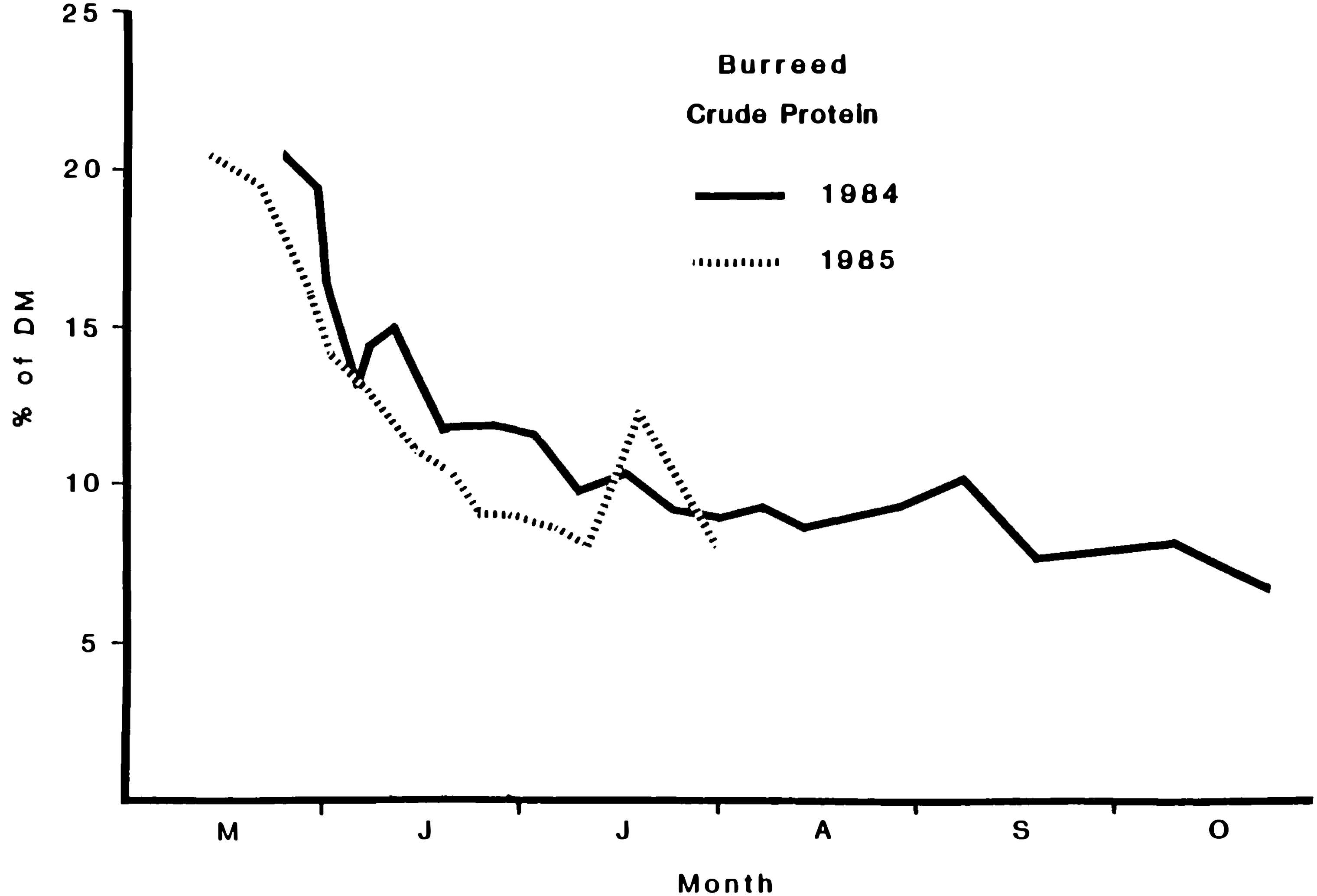

Figure 5. CP content (% of dry matter) of burreed shoots collected in 1984 and 1985.

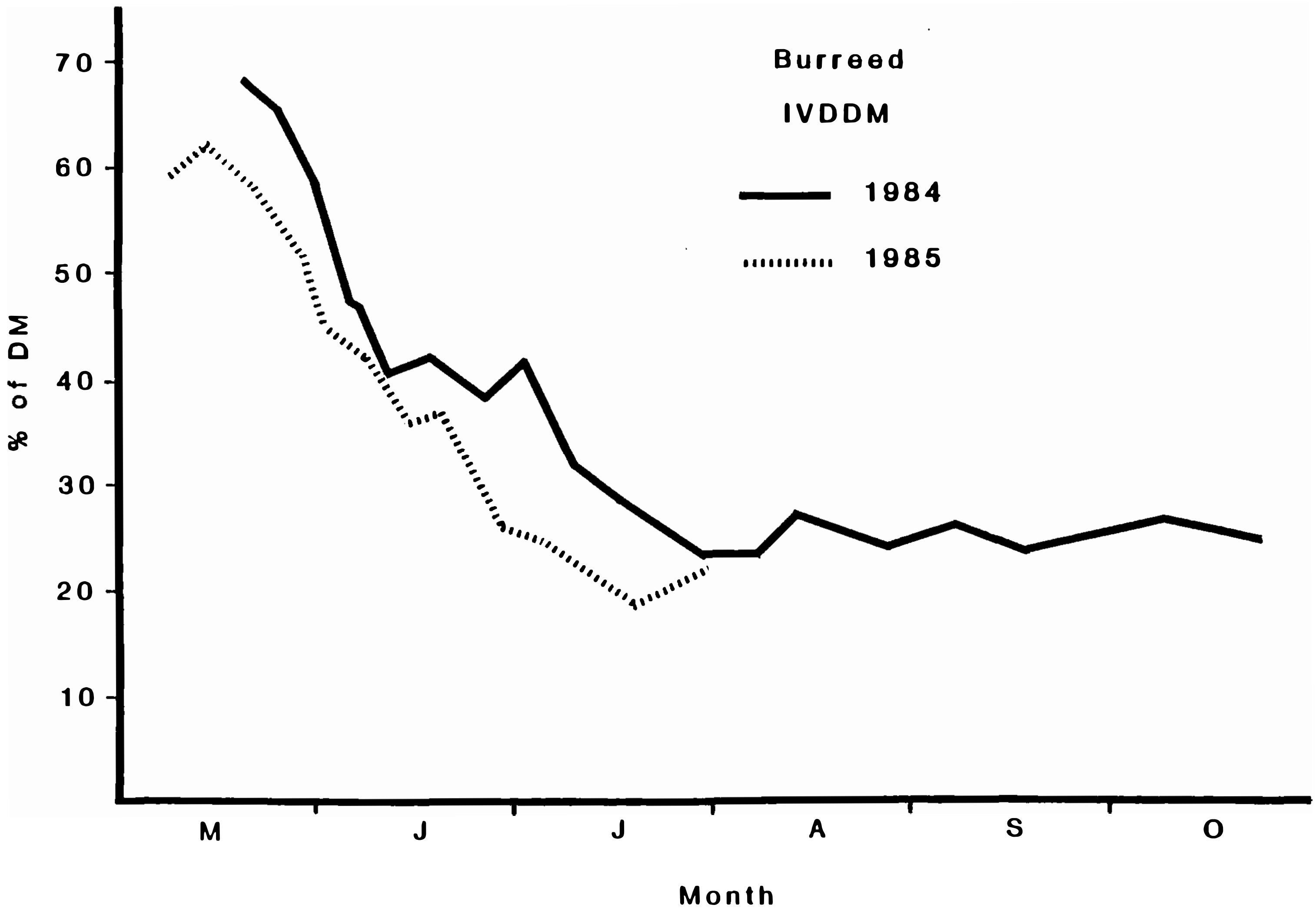

Figure 6. IVDDM (% of dry matter) of burreed shoots collected in 1984 and 1985.

1984 data show that IVDDM remained at these extremely low values for the remainder of the growing season.

Ash values for burreed (Tables 12 and 13) were generally 1.5 to 2 times higher than those for whitetop and at least a few points higher than those for slough sedge. The detergent fiber values (Tables 12 and 13) were similar to those for whitetop and slough sedge, but NDF tended to be lower early in the growing season. Values for ADL, however, were much higher for burreed than the other 2 species (Table 12). Linn et al. (1975) reported similar NDF and ADF values for this species in a late summer collection from Minnesota (60.2 and 42.2%, respectively) but their reported ADL value was only about half (4.73%) of the late summer values found in this study.

The discrepancy between ADF1 and ADF2 values (Table 12) was about the same as for whitetop and slough sedge, however, this difference is probably not accounted for by silica. Silica values on the 5 dates in 1985 used for analyses were always 0.3% or less (Table 13). This suggests either pectins or tannins were responsible for differences in ADF's. Due to the high digestibility of pectins and the lack of digestibility of tannins in ruminants (Van Soest 1982), and the low IVDDM of burreed during the latter half of the growing season, this species probably contains a significant amount of tannin. Other circumstantial evidence of the existence of high tannin content is that this species cured to a tan-brown color. Phlobaphenes could be responsible for this color. Phlobaphenes are polymerized tannins that are not only brown in color, but also may be measured as lignin (Van Soest 1982) and could account for the high ADL values for this species.

Table 12. Chemical constituents of burreed shoots collected from a single stand in 1984 (n = 1 for each line).

	Percent moisture[a]		Percent of dry matter[b]				
Date	Fresh	Air-dry	Ash	NDF	ADF1[c]	ADF2[d]	ADL
5-24	90.3	39.0	14.50	53.7	24.1	24.0	2.91
5-29	89.2	13.6	13.80	53.9	25.0	27.6	3.39
5-31	90.6	13.2	14.40	64.3	32.7	34.4	5.63
6-05[e]	89.5	11.1	13.70	68.2	35.9	39.5	7.04
6-07[f]	89.9	24.3	11.90	65.9	33.5	36.5	7.21
6-11[g]	90.0	9.2	11.40	66.5	33.9	36.6	4.97
6-18[h]	88.1	16.4	11.10	67.1	35.0	36.6	4.94
6-26[i]	86.1	17.8	11.30	66.5	36.0	36.1	5.60
7-02[j]	86.2	12.0	11.50	68.0	37.0	37.0	7.65
7-09	84.6	12.2	11.10	69.0	38.4	39.2	6.47
7-16	82.8	16.6	10.20	68.9	37.5	40.9	6.42
7-23	82.6	1^{2}.8	10.30	70.2	41.6	42.0	9.66
7-30[k]	80.0	9.8	10.50	70.9	42.5	43.6	11.10
8-06	77.2	9.7	9.52	71.4	45.4	44.8	12.60
8-13	74.2	15.0	10.90	69.8	40.6	42.2	9.91
8-27	67.3	8.6	8.59	69.5	39.1	41.9	11.70
9-07[l]	76.5	22.4	10.60	68.6	39.5	40.0	9.59
9-18[m]	57.6	19.1	9.48	72.3	41.1	42.6	9.85
10-09	76.3	15.8	6.12	78.9	45.1	47.7	11.90
10-23	70.6	25.7	4.98	82.7	48.3	53.1	12.00

[a]Approximate; based on dry matter at 60°C.
[b]Dry matter at 100°C.
[c]ADF1 = ADF after extraction for NDF.
[d]ADF2 = ADF without pre-extraction for NDF.
[e]Boot stage evident in earliest flowering shoots.
[f]"Tillering" began.
[g]Anthesis began.
[h]New rhizome elongation.
[i]Seed fill stage began on earliest of flowering shoots.
[j]Seed ripening began on earliest of flowers.
[k]Anthesis terminated on latest of flowering shoots.
[l]Flowering shoots senescent; seed shattered.
[m]About half of plants scenescent.

Table 13. Chemical constituents of burreed shoots collected in 1985 (n = 1 for each line).

	Percent moisture[a]		Percent of dry matter[b]	
Date	Fresh	Air-dry	Ash	Silica
		Single stand collections		
5-13	91.8	18.3	15.50	0.30
5-20	91.4	23.6	15.20	—
5-28	89.8	24.5	14.30	0.20
6-01[c]	89.8	21.9	13.70	—
6-07	87.4	20.5	12.30	—
6-14[d]	86.4	20.3	11.50	0.05
6-19[e]	84.5	17.5	9.93	—
6-24	84.0	17.4	10.60	—
6-28[f]	85.2	17.7	10.30	—
7-05	80.8	16.6	9.66	0.20
7-10	81.0	17.9	9.73	—
7-18[g]	76.0	16.3	8.97	—
7-29[h]	74.7	16.5	8.79	0.20
		Additional stand collections		
7-29	79.5	14.9	9.57	—
7-29	72.8	16.3	7.45	—
8-09	79.8	17.2	11.20	—
8-09	86.6	19.5	11.60	—

[a]Approximate; based on dry matter at 60°C.
[b]Dry matter at 100°C.
[c]Boot stage evident earliest flowering shoots. "Tillering" began.
[d]Anthesis began.
[e]New rhizome elongation.
[f]Seed fill stage began on earliest of flowering shoots.
[g]Anthesis terminated on latest of flowering shoots.
[h]New shoots arising from distal ends of new rhizomes.

Smartweed

The smartweed stand used for both shoot analyses and rhizome TNC analyses in 1984 was heavily infested with Dysonchia procera (Coleoptera: Chrysomelidae) (specimens identified by J. L. Krysan), a beetle that is apparently host-specific on Polygonum. Both adult and larvae are phytophagous. Many leaves in the stand were already damaged by these insects on the first collection date in 1984 and by the middle of July were severely damaged (although new leaves had been consistently appearing at the tops of the plants). By late July, however, new branches were elongating from buds at lower nodes of the aerial shoots and by mid August new leaves were abundant throughout the stand. The trends in CP and IVDDM reflected this scenario (Figures 7 and 8). Only a few shoots in this stand flowered in mid August. When sampling was to resume in late April of the following spring, smartweed shoots had not yet emerged. When only sparse stunted shoots had emerged by mid June, it was decided to take smartweed samples from a different site in a seasonal-wetland-dominated basin a few hundred meters to the east. Dysonchia activity was also a problem at the site used in 1985. The stand did not flower prior to termination of sampling (10 August) in that year. Although some new shoots began arising from lower nodes on some stems on 29 July, they were not quantitatively important in the collections at termination of sampling.

CP levels in smartweed at the beginning of the 1984 growing season were over 20% and peaked again near 20% after the profusion of new shoots in August (Figure 7). Smartweed generally exhibited higher CP levels throughout the 1984 growing season than the other 3 species

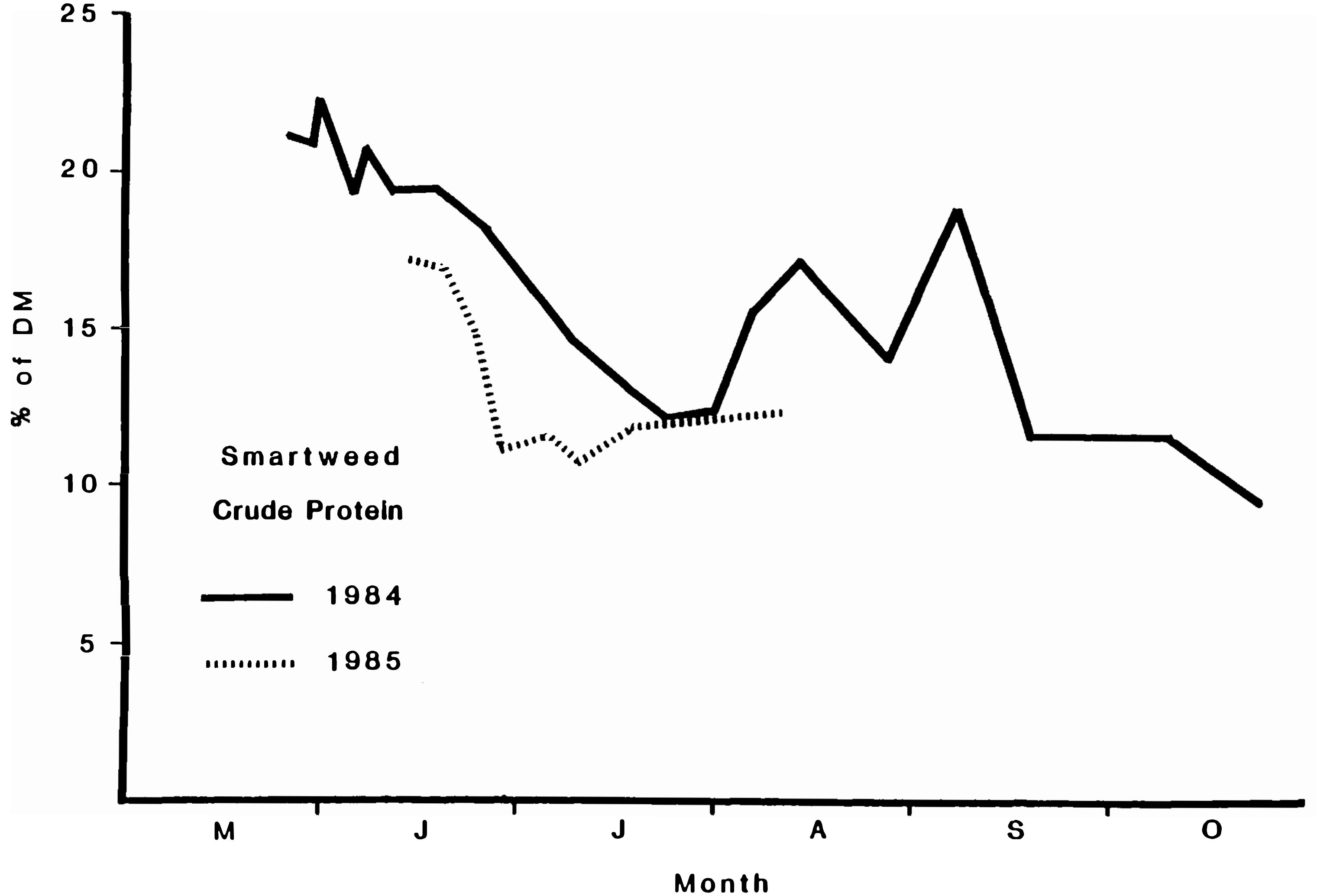

Figure 7. CP content (% of dry matter) of smartweed shoots collected in 1984 and 1985.

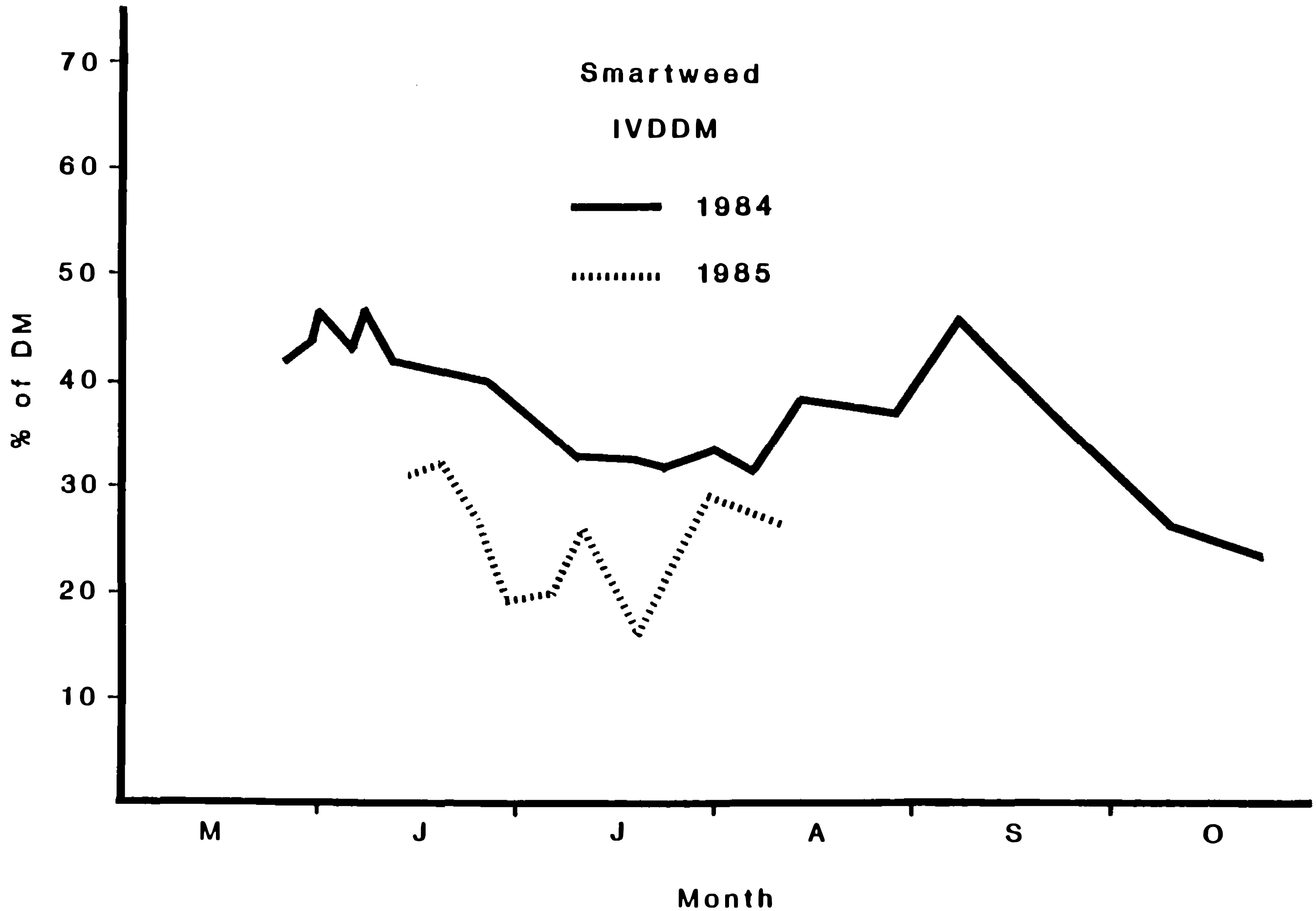

Figure 8. IVDDM (% of dry matter) of smartweed shoots collected in 1984 and 1985.

studied. The only time that CP dropped below 11.5% was on the last sampling date (9.3% on 23 October). Although samples were only collected from 14 June through 10 August in 1985, and CP levels were lower in that year, the data followed the same trend as in the previous year. CP values never dropped below 10.8% during the 1985 collection period.

The high CP content in smartweed may be due to either an inherently high N content, or to a delay in maturation of the plant caused by the defoliation. Any factor which retards the normal maturation process usually results in suppression of the decline in forage quality that typically accompanies maturation (Van Soest 1982). Korelyakova (1971) reported a CP content of 27.3% for _P. amphibium_ in a July collection in the Ukrainian S.S.R. However, by the description of the plant in his paper, it appears that his specimens may have been _P. a. stipulaceum_, while in the present study _P. a. emersum_ was the form used. This distinction is pointed out as there is controversy in the taxonomy of this species, and the latter has long been regarded as _P. coccineum_ (see Great Plains Flora Association 1986). Looman (1983) reports that water smartweed hay (_Polygonum_ spp.) in Canada will typically have at least 15% CP content if green and leafy.

IVDDM of smartweed was never as high in these collections as the other 3 species studied were at their peaks. In 1984, IVDDM was in the 40 to 46% range during the initial early growing season peak and reached 46% again at the peak following refoliation (Figure 8). In 1985 the IVDDM content was lower at comparable dates than in 1984, and rather erratic.

Ash values for smartweed (Tables 14 and 15) were similar to those found for whitetop and slough sedge. NDF values, however, were generally lower than for the other species studied (Table 14). ADF values, on the other hand, were similar to those found in the other 3 species. It is interesting to note that in 11 out of the 20 samples collected in 1984, ADF2 values were less than ADF1 values. One would have expected all ADF2 values to be consistently larger than their ADF1 counterparts as, in a European study of this genus, it was found that P. amphibium contained large amounts of tannins (Krzaczek et al. 1974). The red color of smartweed stems may be indicative of the presence of condensed tannins (Van Soest 1982). In cases where the ADF2 values are higher than ADF1, it is reasonable to assume that the difference is due to tannins as silica levels on all 3 dates tested in 1985 were low (Table 15). For the opposite situations, aside from possible procedural error, it might be speculated that at certain times a class of compounds exist that are not soluble in neutral detergent and solubilized by acid detergent. ADL values for this species were very high relative to the other 3 species.

Prediction of IVDDM by Chemical Constituents

Whitetop

Data listed in Table 8 were used for regression analyses. NDF, ADL, and ADF1 or ADF2 were found to be collinear. Therefore, equations that contained any combination of these variables were disregarded. The significant single constituent equations and the best multiple regression equation are listed in Table 16. Many other polynomial equations were statistically significant, overall, but were not listed

Table 14. Chemical constituents of smartweed shoots collected from a single stand in 1984 (n = 1 for each line).

	Percent moisture[a]		Percent of dry matter[b]				
Date	Fresh	Air-dry	Ash	NDF	ADF1[c]	ADF2[d]	ADL
5-24	82.5	12.8	7.51	49.4	34.8	29.4	7.29
5-29	80.5	11.6	7.73	49.3	35.9	33.1	12.90
5-31	80.8	11.0	8.51	57.6	40.6	36.6	17.20
6-05	80.8	10.2	7.50	57.5	42.0	41.5	15.80
6-07	80.5	18.7	6.77	58.0	40.5	35.5	13.30
6-11[e]	81.0	7.9	6.30	60.4	42.6	39.5	14.70
6-18	79.3	8.4	7.41	60.8	42.9	39.8	15.90
6-26	74.1	14.8	6.16	57.6	38.6	38.9	12.90
7-02	69.9	11.8	6.38	62.2	43.7	40.3	16.70
7-09	76.3	10.1	6.87	60.8	42.0	43.8	14.50
7-16	60.2	14.2	6.16	63.1	44.0	40.4	16.00
7-23	65.9	13.7	5.05	63.6	43.4	45.2	13.90
7-30	67.5	9.3	5.75	61.7	42.0	43.9	14.10
8-06	72.2	9.3	7.10	58.3	42.3	42.0	14.70
8-13[f]	76.2	16.3	7.20	54.6	37.7	39.8	12.10
8-27	70.3	8.5	5.38	51.0	35.8	35.2	9.81
9-07	80.0	29.5	7.65	49.5	35.2	37.0	12.00
9-18	68.2	17.8	5.33	50.2	35.0	36.1	9.97
10-09[g]	72.6	17.3	5.74	70.7	50.1	53.2	20.00
10-23	70.7	12.9	4.26	73.4	55.2	59.1	19.60

[a] Approximate; based on dry matter at 60°C.
[b] Dry matter at 100°C.
[c] ADF1 = ADF after extraction for NDF.
[d] ADF2 = ADF without pre-extraction for NDF.
[e] New rhizome/shoot elongation.
[f] Flowering occurred on small percentage of shoots. Profusion of new shoots from old rhizomes and stems.
[g] About half of all shoots senescent.

Table 15. Chemical constituents of smartweed shoots collected in 1985 (n = 1 for each line).

	Percent moisture[a]		Percent of dry matter[b]		
Date	Fresh	Air-dry	Ash	ADF2[c]	Silica
		Single stand collections			
6-14	74.6	17.3	5.72	30.5	0.34
6-19	74.8	15.8	5.85	30.9	—
6-24	70.6	16.3	5.41	29.1	—
6-28[d]	69.0	16.3	4.74	34.6	—
7-05	68.7	15.3	4.74	32.6	0.18
7-10	66.3	16.1	5.02	34.7	—
7-18	67.4	14.9	5.10	32.5	—
7-29[e]	70.3	16.0	5.68	37.0	0.36
8-10	67.7	15.0	6.03	38.9	—
		Additional stand collections			
7-24	70.3	19.2	5.53	41.4	—
7-24	69.3	16.5	6.51	44.0	—
7-29	73.3	16.0	7.16	38.8	—
8-09	75.7	15.8	7.35	38.8	—
8-09	74.4	15.4	6.72	43.3	—

[a]Approximate; based on dry matter at 60^{o}c.
[b]Dry matter at 100^{o}c.
[c]ADF2 = ADF without pre-extraction for NDF.
[d]New shoots began arising from lower nodes on stems.
[e]New rhizomes elongating.

Table 16. Significant linear and polynomial regressions of IVDDM on single chemical constituents[a] and best multiple regression for whitetop based on 1984 collections (n = 20).

Equation (IVDDM =)	R^2	Significance (P<) Equation	Significance (P<) R^2 Improvement[b]
Linear and Polynomial Equations			
1.817 (CP) + 23.76	0.58	0.0001	—
3.878 (ash) + 15.84	0.26	0.02	—
-57.51 (ash) + 4.802 (ash^2) + 203.2	0.60	0.0004	0.01
-1.773 (ADF1) + 106.2	0.64	0.0001	—
-172.9 (ADF1) + 4.421 ($ADF1^2$) - 0.0377 ($ADF1^3$) + 2295	0.78	0.0001	0.05
-1.678 (ADF2) + 106.4	0.66	0.0001	—
-163.0 (ADF2) + 3.890 ($ADF2^2$) - 0.0309 ($ADF2^3$) + 2315	0.82	0.0001	0.01
-0.7636 (NDF) + 95.13	0.26	0.02	—
-5.874 (ADL) + 73.15	0.75	0.0001	—
-96.55 (ADL) + 17.67 (ADL^2) - 1.083 (ADL^3) + 216.0	0.88	0.0001	0.001
Multiple Regression Equation			
1.244 (CP) - 1.246 (ADF2) + 78.38	0.89	0.0001	0.001

[a]CP = crude protein, ADF1 and ADF2 = acid detergent fiber (see text), NDF = neutral detergent fiber, ADL = acid detergent lignin.
[b]Improvement over next lowest order polynomial.

in Table 16 if the addition of a squared or cubed term did not significantly ($p<0.05$) improve the R^2 value over its next lowest order polynomial counterpart.

All regressions listed in Table 16, except the linear ash and linear NDF equations, have R^2 values that are higher than the R^2 values given for the 3 quadratic type equations listed by Rohweder et al. (1981) for tame forage species (R^2 = 0.57, 0.56, and 0.53 for alfalfa, grasses, and all species equations respectively). All 3 of the equations of Rohweder et al. (1981) were quadratic-type with ADF as the independent variable. The equations developed by those authors were based on <u>in vivo</u> DDM. They did not report if the ADF procedures were conducted with pre-extraction with neutral detergent solution or not. The much higher R^2 values found in the present study are probably due to the typically better statistical relationships of chemical constituents with digestibility when only plant age and maturity effects are the primary variables affecting the plants (Van Soest 1982). Relationships between various constituents and digestibility can vary not only between species, but between first cuttings and aftermath cuttings, and with environment.

In whitetop, quadratic forms of both ADF1 and ADF2 did not significantly improve ($p>0.05$) R^2 values of linear equations. However, in both cases, cubic forms did significantly improve R^2 values. The ADF2 cubic equation did a slightly better job of explaining variation in IVDDM than did the ADF1 cubic equation. This should be expected as 1985 analyses (Table 9) showed this species was high in silica. Silica is included in the ADF2 fraction, but only partly included in the ADF1 fraction. Although the effect of silica on digestibility varies with plant species, in temperate and northern grasses the effect seems to be an inhibitory one (Van Soest 1982). This effect can be as much as a 2 to 3 unit drop in digestibility per unit of silica. The best single constituent equation for whitetop was the cubic regression of ADL (R^2 = 0.88).

The best of all equations was the multiple regression using CP and ADF2 as the independent variables (Table 16; R^2 = 0.89). This equation was used to predict the IVDDM values for whitetop collected in 1985 from the same wetland that was used in 1984, and for samples collected from 3 other sites in eastern South Dakota. Table 17 lists the actual IVDDM, the predicted IVDDM, and whether or not the predicted value was within $\pm$ 5 and $\pm$ 10% of the actual value. Six out of 17 predictions (35%) were within $\pm$ 5% of actual and 14 out of 17 (82%) were within $\pm$ 10%. All predictions were within 13% of actual values. This practical "test" of the equation shows that at least in this wetland, the equation appears to be able to predict reasonably well; especially when one considers that 18% of the variation in IVDDM remains unexplained by the prediction equation.

Slough Sedge

The significant regression equations for this species are listed in Table 18. There were no multiple regressions that significantly improved the R^2 values of single constituent equations. Several collinearity problems existed between independent variables in slough sedge which greatly limited the combinations that could be tried in multiple regressions (CP, ADF1 or ADF2, and NDF were collinear as well

Table 17. Comparison of IVDDM predicted by multiple regression equation[a] with actual IVDDM for 1985 whitetop collections.

Date	IVDDM Actual	IVDDM Predicted	Difference	Limit ±5%	Limit ±10%	Within limit? 5%	Within limit? 10%
			Single stand collections				
5-08	52.5	56.4	-3.9	2.6	5.2	No	Yes
5-13	54.4	55.9	-1.5	2.7	5.4	Yes	Yes
5-20	53.0	52.2	0.8	2.7	5.3	Yes	Yes
5-28	46.3	42.7	3.6	2.3	4.6	No	Yes
6-01	46.5	45.2	1.3	2.3	4.7	Yes	Yes
6-07	43.1	39.6	3.5	2.2	4.3	No	Yes
6-14	40.2	39.6	0.6	2.0	4.0	Yes	Yes
6-19	42.5	37.3	5.2	2.1	4.2	No	No
6-24	43.8	41.4	2.4	2.2	4.4	No	Yes
6-28	41.4	36.7	4.4	2.1	4.1	No	No
7-05	44.3	40.9	3.4	2.2	4.4	No	Yes
7-10	40.2	38.0	2.2	2.0	4.0	No	Yes
7-18	39.3	38.0	1.3	2.0	3.9	Yes	Yes
7-29	39.2	37.0	2.2	2.0	3.9	No	Yes
			Additional stand collections				
7-10	31.0	29.0	2.0	1.5	3.1	No	Yes
7-29	32.9	37.2	-4.3	1.6	3.3	No	No
8-09	34.6	34.3	0.3	1.7	3.5	Yes	Yes

[a]IVDDM = 1.244 (CP) - 1.246 (ADF2) + 78.38.

Table 18. Significant linear and polynomial regressions of IVDDM on single chemical constituents[a] for slough sedge based on 1984 collections (n = 20).

Equation (IVDDM =)	R^2	Significance (P<) Equation	Significance (P<) R^2 Improvement[b]
Linear and Polynomial Equations			
2.334 (CP) + 24.53	0.92	0.0001	—
5.367 (CP) - 0.1185 (CP^2) + 7.643	0.96	0.0001	0.001
7.375 (ash) - 8.977	0.20	0.05	—
-3.329 (ADF1) + 170.2	0.81	0.0001	—
-2.821 (ADF2) + 161.2	0.77	0.0001	—
216.3 (ADF2) - 5.673 ($ADF2^2$) + 0.0486 ($ADF2^3$) - 2634	0.83	0.0001	0.05
-2.437 (NDF) + 227.2	0.42	0.002	—
-14.34 (ADL) + 111.8	0.72	0.0001	—

[a]CP = crude protein, ADF1 and ADF2 = acid detergent fiber (see text), NDF = neutral detergent fiber, ADL = acid detergent lignin.
[b]Improvement over next lowest order polynomial.

as ash and ADL). Although the cubic regression of ADF2 gave an R^2 value that was better than that for whitetop (Table 16), the quadratic CP equation was by far the best equation with an R^2 of 0.96. Hubbard et al. (1987), in a study of hybrid cattail (Typha glauca), also found CP to be the best potential predictor of IVDDM. In that study, both the linear CP regression (R^2 = 0.89) and the cubic (R^2 = 0.92) had higher R^2 values than any other regression equation using other chemical constituents. In contrast, Oh et al. (1966) and Van Soest and Mertens (1977), using more traditional forages, found that either detergent fiber fractions or ADL produced higher correlations with *in vivo* DDM than did CP.

Results of using the cubic CP equation to predict the 1985 slough sedge IVDDM are presented in Table 19. In addition to plants collected from the same stand, additional slough sedge collections were made from 7 different wetlands in the area. Predicted values were within 5% of actual in 11 out of 22 samples (50%) and within 10% in 19 samples (86%). All but 1 value were within 12% of the actual. The sample with the largest discrepancy had a predicted value about 20% lower than the actual IVDDM.

Burreed

Significant regression equations for burreed IVDDM are listed in Table 20. Collinearity problems occurred with NDF and both ADF fractions. The linear regression with CP and the cubic regression with ADF1 both had R^2 values of 0.92. The best equation was a multiple regression that included CP, ash, and ash^2 that significantly improved ($p<0.01$) the R^2 value (0.95) over that of the linear CP equation. Using

Table 19. Comparison of IVDDM predicted by polynomial regression equation[a] with actual IVDDM for 1985 slough sedge collections.

Date	IVDDM Actual	IVDDM Predicted	Difference	Limit ±5%	Limit ±10%	Within limit? 5%	Within limit? 10%
			Single stand collections				
5-02	55.2	58.6	-3.4	2.8	5.5	No	Yes
5-08	55.5	57.3	-1.8	2.8	5.5	Yes	Yes
5-13	63.3	65.5	-2.2	3.2	6.3	Yes	Yes
5-20	60.0	61.9	-1.9	3.0	6.0	Yes	Yes
5-28	58.5	61.6	-3.1	2.9	5.9	No	Yes
6-01	52.3	57.1	-4.8	2.6	5.2	No	Yes
6-07	58.3	57.1	1.2	2.9	5.8	Yes	Yes
6-14	53.2	50.9	2.3	2.7	5.3	Yes	Yes
6-19	56.0	52.9	3.1	2.8	5.6	No	Yes
6-24	49.2	44.8	4.4	2.5	4.9	No	Yes
6-28	53.1	48.3	4.8	2.7	5.3	No	Yes
7-05	52.4	41.7	10.7	2.6	5.2	No	No
7-10	48.3	42.6	5.7	2.4	4.8	No	No
7-18	46.4	44.8	1.6	2.3	4.6	Yes	Yes
7-29	41.5	43.5	-2.0	2.1	4.2	Yes	Yes
			Additional stand collections				
6-28	49.1	50.3	-1.2	2.5	4.9	Yes	Yes
7-24	46.2	40.8	5.4	2.3	4.6	No	No
7-24	48.7	46.1	2.6	2.4	4.9	No	Yes
7-29	38.1	38.5	-0.4	1.9	3.8	Yes	Yes
7-29	38.3	38.4	-0.1	1.9	3.8	Yes	Yes
8-09	45.5	48.1	-2.6	2.3	4.5	No	Yes
8-09	43.9	44.4	-0.5	2.2	4.4	Yes	Yes

[a]IVDDM = 5.367 (CP) - 0.1185 (CP^2) + 7.643.

Table 20. Significant linear and polynomial regressions of IVDDM on single chemical constituents[a] and best multiple regression for burreed based on 1984 collections (n = 20).

Equation (IVDDM =)	R^2	Significance (P<) Equation	R^2 Improvement[b]
Linear and Polynomial Equations			
3.62 (CP) -5.420	0.92	0.0001	—
4.669 (ash) - 13.65	0.62	0.0001	—
-11.92 (ash) + 0.8240 (ash^2) + 64.79	0.86	0.0001	0.001
-2.123 (ADF1) + 116.6	0.83	0.0001	—
39.83 (ADF1) - 1.253 (ADF1^2) + 0.0121 (ADF1^3) - 334.4	0.92	0.0001	0.01
-1.931 (ADF2) + 112.7	0.75	0.0001	—
-5.721 (ADF2) + 0.0497 (ADF2^2) + 182.9	0.81	0.0001	0.05
28.82 (ADF2) - 0.8743 (ADF1^2) + 0.0080 (ADF2^3) - 230.9	0.88	0.0001	0.01
-1.810 (NDF) + 160.4	0.69	0.0001	—
-8.655 (NDF) + 0.0510 (NDF^2) + 388.0	0.76	0.0001	0.01
154.4 (NDF) - 2.380 (NDF^2) + 0.0119 (NDF^3) - 3208	0.86	0.0001	0.01
-3.952 (ADL) + 68.47	0.69	0.0001	—
-11.71 (ADL) + 0.4853 (ADL^2) + 95.28	0.76	0.0001	0.05
Multiple Regression Equation			
2.614 (CP) - 6.674 (ash) + 0.3971 (ash^2) + 29.88	0.95	0.0001	0.01

[a] CP = crude protein, ADF1 and ADF2 = acid detergent fiber (see text), NDF = neutral detergent fiber, ADL = acid detergent lignin.
[b] Improvement over next lowest order polynomial.

this equation to predict 1985 IVDDM values for plants from the same stand and 4 collections of burreed from other local wetlands showed that only 6 out of 17 (35%) were within 5% of the actual value and 8 (47%) were within 10% (Table 21). The poor performance of the equation, especially in view of the high R^2, serves to reinforce the need for the testing of predictive equations. The failure of this equation to reasonably predict IVDDM from plants taken from the same stand is obvious proof that the equation is worthless as a predictor. The high R^2 could have been spurious; in which case the selection of a different equation may have given better predictions.

Smartweed

All chemical constituents in the 1984 smartweed samples produced significant linear regression equations (Table 22). However, no polynomial regressions significantly improved the R^2 over their linear counterparts. The best linear equation was that of CP ($R^2 = 0.78$). The best equation was a multiple regression on CP and ADF1 ($R^2 = 0.88$). But this was not the equation selected for testing. The CP and ADF2 multiple regression (Table 22) was selected instead. Although this equation had an R^2 value of 0.86, 2 units lower than the best R^2, it was rationalized that this difference in R^2 values was probably inconsequential as most polynomial and multiple regressions typically needed R^2 improvements over lower order equations of greater than a 2 unit difference for statistical significance. The overriding factor being that costs of analysis for ADF2 are about half of those for ADF1.

The prediction equation did the worst job of predicting 1985 IVDDM compared to equations selected for the other 3 species (Table 23).

Table 21. Comparison of IVDDM predicted by multiple regression equation[a] with actual IVDDM for 1985 burreed collections.

Date	IVDDM Actual	IVDDM Predicted	Difference	Limit ±5%	Limit ±10%	Within limit? 5%	Within limit? 10%
			Single stand collections				
5-13	61.4	75.0	-13.6	3.1	6.1	No	No
5-20	58.4	71.1	-12.7	2.9	5.8	No	No
5-28	51.9	57.2	-5.3	2.6	5.2	No	No
6-01	44.9	49.7	-4.8	2.2	4.5	No	No
6-07	42.0	41.5	0.5	2.1	4.2	Yes	Yes
6-14	35.5	34.8	0.7	1.8	3.5	Yes	Yes
6-19	36.5	29.9	6.6	1.8	3.7	No	No
6-24	29.8	27.3	2.5	1.5	3.0	No	Yes
6-28	25.8	26.8	-1.0	1.3	2.6	Yes	Yes
7-05	24.4	24.9	-0.5	1.2	2.4	Yes	Yes
7-10	22.0	23.5	-1.5	1.1	2.2	No	Yes
7-18	18.0	34.3	-16.3	0.9	1.8	No	No
7-29	21.4	23.5	-2.1	1.1	2.1	No	No
			Additional stand collections				
7-29	30.6	31.3	-0.7	1.5	3.1	Yes	Yes
7-29	20.3	20.3	0.0	1.0	2.0	Yes	Yes
8-09	21.5	31.3	-9.8	1.1	2.1	No	No
8-09	36.5	40.7	-4.2	1.8	3.7	No	No

[a]IVDDM = 2.614 (CP) - 6.674 (ash) + 0.3971 (ash^2) + 29.87.

Table 22. Significant linear and polynomial regressions of IVDDM on single chemical constituents[a] and best multiple regressions for smartweed based on 1984 collections (n = 20).

Equation (IVDDM =)	R^2	Significance (P<) Equation	R^2 Improvement[b]
Linear Equations			
1.531 (CP) + 12.42	0.78	0.0001	—
4.470 (ash) + 8.226	0.52	0.0003	—
-0.9435 (ADF1) + 76.34	0.53	0.0003	—
-0.8226 (ADF2) + 70.78	0.68	0.0001	—
-0.7299 (NDF) + 80.14	0.54	0.0002	—
-1.004 (ADL) + 51.67	0.22	0.03	—
Multiple Regression Equations			
1.200 (CP) - 0.4766 (ADF1) + 37.48	0.88	0.0001	0.01
1.039 (CP) - 0.3988 (ADF2) + 36.61	0.86	0.0001	0.01

[a]CP = crude protein, ADF1 and ADF2 = acid detergent fiber (see text), NDF = neutral detergent fiber, ADL = acid detergent lignin.
[b]Improvement over next lowest order polynomial.

Table 23. Comparison of IVDDM predicted by multiple regression equation[a] with actual IVDDM for 1985 smartweed collections.

Date	IVDDM Actual	IVDDM Predicted	Difference	Limit ±5%	Limit ±10%	Within limit? 5%	Within limit? 10%
			Single stand collections				
6-14	30.8	42.4	-11.6	1.5	3.1	No	No
6-19	31.7	41.7	-10.0	1.6	3.2	No	No
6-24	27.0	40.1	-13.1	1.4	2.7	No	No
6-28	20.0	34.4	-14.4	1.0	2.0	No	No
7-05	21.4	35.6	-14.2	1.1	2.1	No	No
7-10	26.2	34.0	-7.8	1.3	2.6	No	No
7-18	16.0	35.9	-19.9	0.8	1.6	No	No
7-29	28.7	34.2	-5.5	1.4	2.9	No	No
8-10	26.3	33.8	-7.5	1.3	2.6	No	No
			Additional stand collections				
7-24	21.7	30.6	-8.9	1.1	2.2	No	No
7-24	23.4	31.7	-8.3	1.2	2.3	No	No
7-29	29.4	36.3	-6.9	1.5	2.9	No	No
8-09	39.2	33.5	5.7	2.0	3.9	No	NO
8-09	31.1	33.1	-2.0	1.6	3.1	No	Yes

[a]IVDDM = 1.039 (CP) - 0.3988 (ADF2) + 36.61.

Only 1 prediction out of 14 was within 10% of the actual value. The stress imposed upon these plants by the insects probably obscured the relationships between the constituents and IVDDM that would have occurred during a normal growing season.

Below Ground TNC

Results of the TNC analyses on the November 1983 collections of whitetop, slough sedge, burreed, and smartweed are shown in Table 24. For 3 of the species, the enzyme hydrolyzable fraction (mono- and disaccharides, amylose, amylopectin) averaged a bit higher than the enzyme plus acid hydrolyzable fractions (enzyme hydrolyzable carbohydrate plus fructosans). The mean enzyme plus acid hydrolyzable fraction in whitetop, however, was about 3.8 times the mean enzyme only fraction. Therefore, in contrast to the other 3 species, whitetop is a fructosan accumulator. Many species of upland Festuceae are also fructosan accumulators (Smith 1968). After verification of the same relationships between the carbohydrate fractions in these species on the first 5 sampling dates in 1984 (data not shown), it was decided to only run acid hydrolysis on whitetop samples. Thus, the TNC values discussed below represent enzyme hydrolyzable values for slough sedge, burreed, and smartweed and enzyme plus acid hydrolyzable values for whitetop.

Whitetop

TNC content was generally higher in 1985 than in 1984 (Figure 9). The lowest TNC values in 1984 occurred on 31 May and 5 June (about 13%). Tillering was first noted on 31 May and the joint/boot stage was prevalent on 7 June (TNC = 21.2%) in that year. In 1985, the lowest TNC content occurred on 28 May (16.1%) when the joint/boot stage was

Table 24. TNC content of rhizomes of 4 species of wetland plants collected on 21 November 1983 (n = 3 for each species).

Species	Mean TNC (% dry matter)	
	Enzyme hydrolyzable[a]	Enzyme and acid hydrolyzable[b]
Carex atherodes	9.8 (0.4)[c]	8.3 (0.6)
Polygonum amphibium var. emersum	14.4 (0.2)	12.0 (0.4)
Scolochloa festucacea	7.9 (0.3)	29.9 (1.7)
Sparganium eurycarpum	14.9 (1.8)	12.9 (1.9)

[a]Includes simple sugars, sucrose, and starch derived carbohydrate.
[b]Includes enzyme hydrolized carbohydrate plus fructosan derived carbohydrate.
[c]Standard error in parentheses.

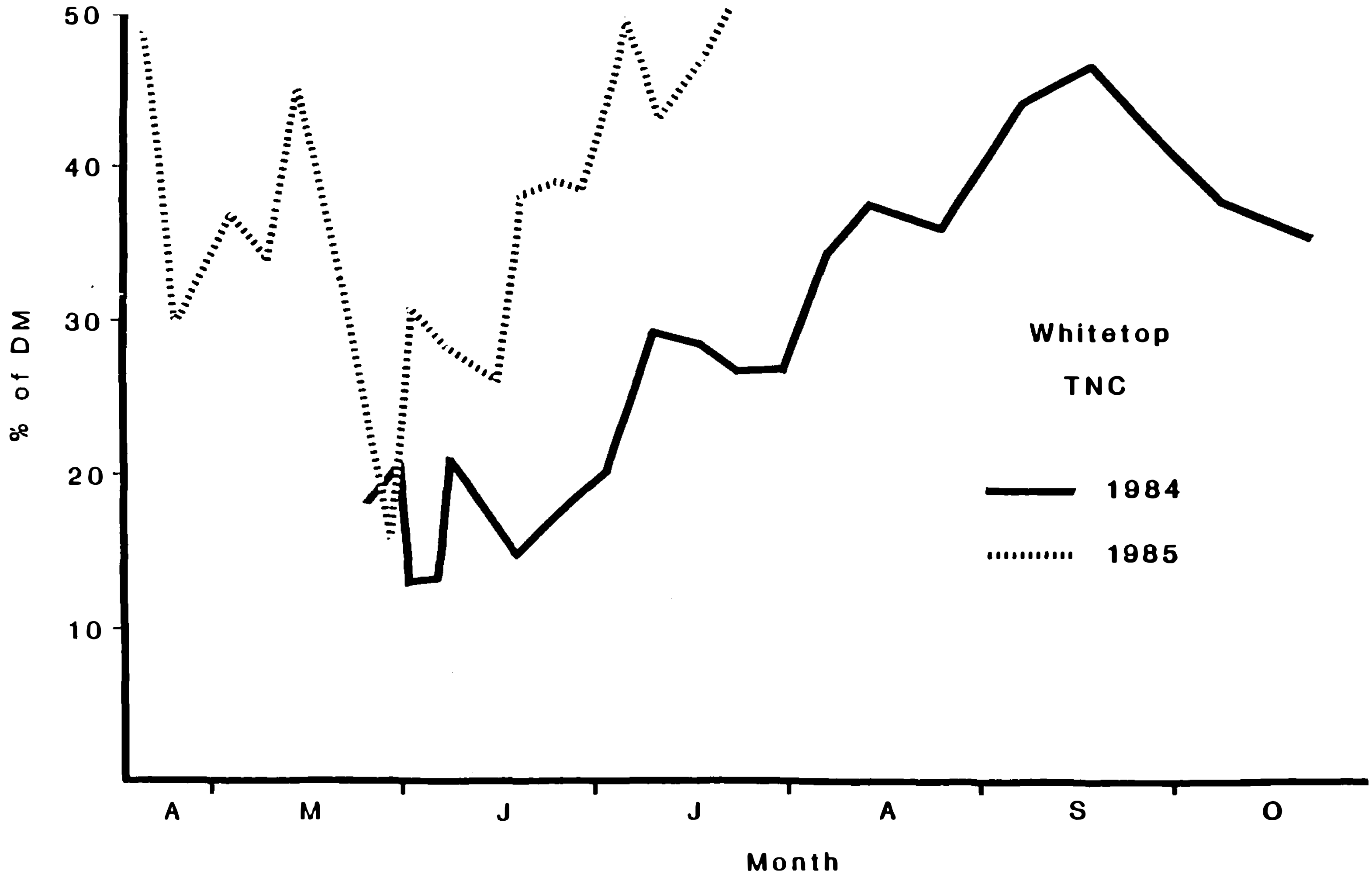

Figure 9. TNC content (% of dry matter) in below ground material of whitetop collected in 1984 and 1985.

evident. Tillering was abundant on 1 June in 1985 (TNC = 31.2%). Although the order in which they occurred was opposite in the 2 years the joint/boot stage and tillering were noted within 7 days of each other in 1984 and within 4 days in 1985. The actual physiological events that occur to produce these observable events are probably commencing at approximately the same time and placing a large demand on stored carbohydrate reserves. The second lowest TNC value occurred in mid June in both years and coincided with anthesis (14.9% in 1984 and 26.3% in 1985). Thereafter, TNC content in below ground material increased in a "stair-step" fashion for the remainder of the growing season. The peak value in 1985 occurred on the last sampling date (29 July) at 57.7%. The peak TNC value occurred in mid-September in 1984 (47%) and then began a decline, presumably due to respirational losses.

The stair-step pattern in TNC content of below ground material may possibly be accounted for by periods of new shoot production. After the first flourish of tillering (noted above), the new rhizomes that were produced elongated outward from the parent shoot (often over 30 cm) and began producing new shoots. New rhizome and new shoot production continued through the remainder of the growing season. Although unquantified, their seemed to be definite cohorts of shoots produced, as on several occasions the shoots clipped for forage quality analyses showed bi- and tri-modal height distributions.

Slough Sedge

The TNC content was generally much lower for this species than in whitetop (Figure 10). Both the lowest and highest TNC values for slough sedge were less than half of the respective values for whitetop.

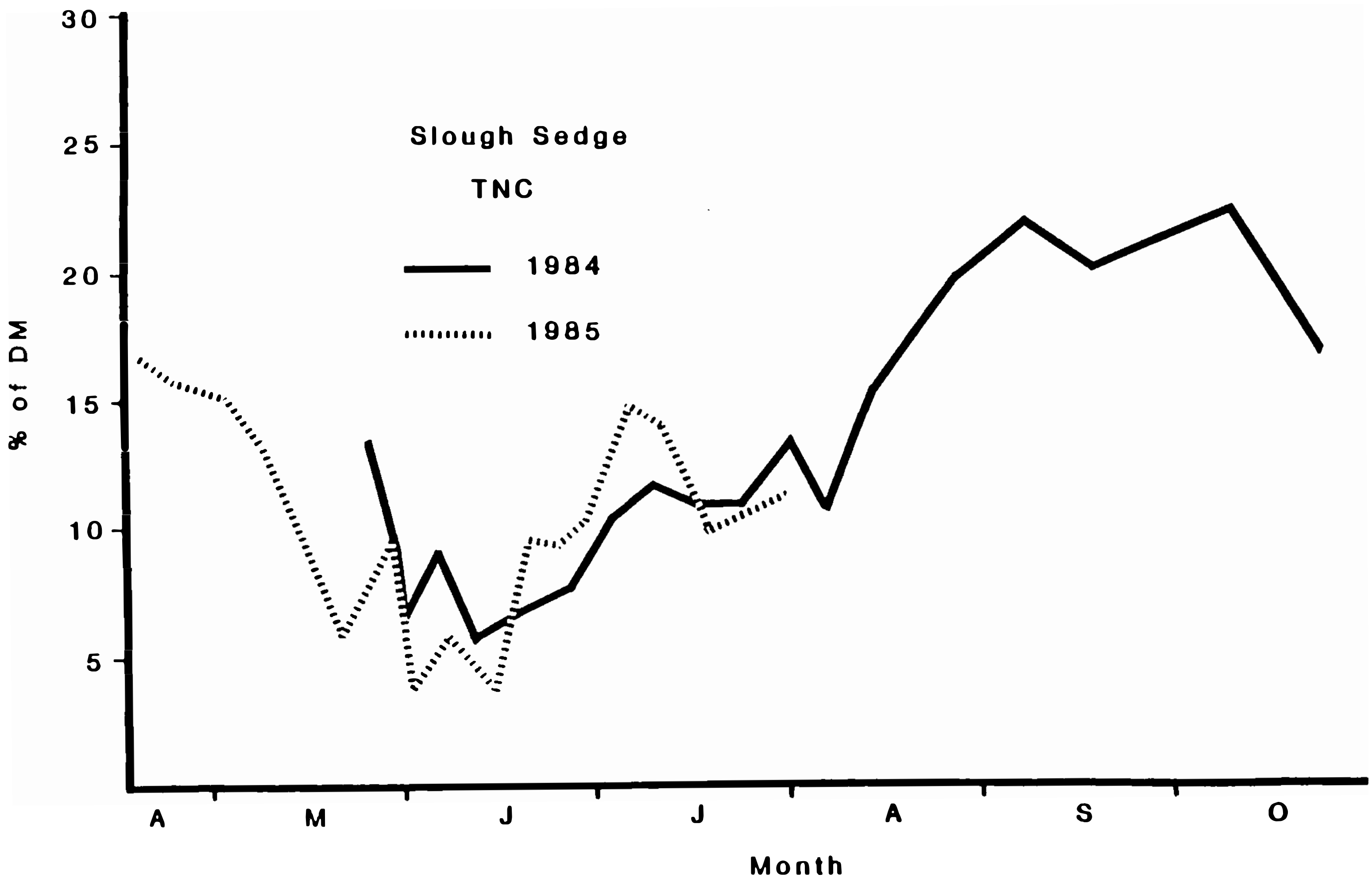

Figure 10. TNC content (% of dry matter) in below ground material of slough sedge collected in 1984 and 1985.

The lowest values in each season for this species occurred in very late May and the first part of June. As in whitetop, the sequence of phenological events for slough sedge differed somewhat in both years. In 1984, the late May to mid-June events were: tillering (5 June), anthesis (7 June), new rhizome elongation (11 June), seed fill (18 June). In 1985, these events were anthesis (28 May), tillering (1 June), seed fill (7 June), new rhizome elongation (24 June). Even though the order of occurrence was different and no distinct event can be associated with a pronounced low point in TNC, the generally low values that occur during this sequence of events indicate that this is the period in the annual cycle of the plant when below ground energy reserves are at a minimum.

Burreed

For this species, a distinct low point in TNC content occurred on 18 June 1984, 7 days after anthesis began on the earliest flowers, and on 7 June 1985, 7 days prior to first anthesis (Figure 11). The first observation of new rhizome elongation coincided with the TNC low point in 1984, but occurred about 2 weeks later than the lowest TNC value in 1985. Although anthesis in this species occurs over several weeks, it appears that anthesis commencement on the earliest heads can be used as an approximate marker for the low point in TNC.

Smartweed

The stress on these plants caused by herbivory was apparent in the TNC data (Figure 12). The erratic nature of the graphs probably represents the repetitive utilization of energy reserves for growth of new leaves intermingled with brief periods of respite from defoliation.

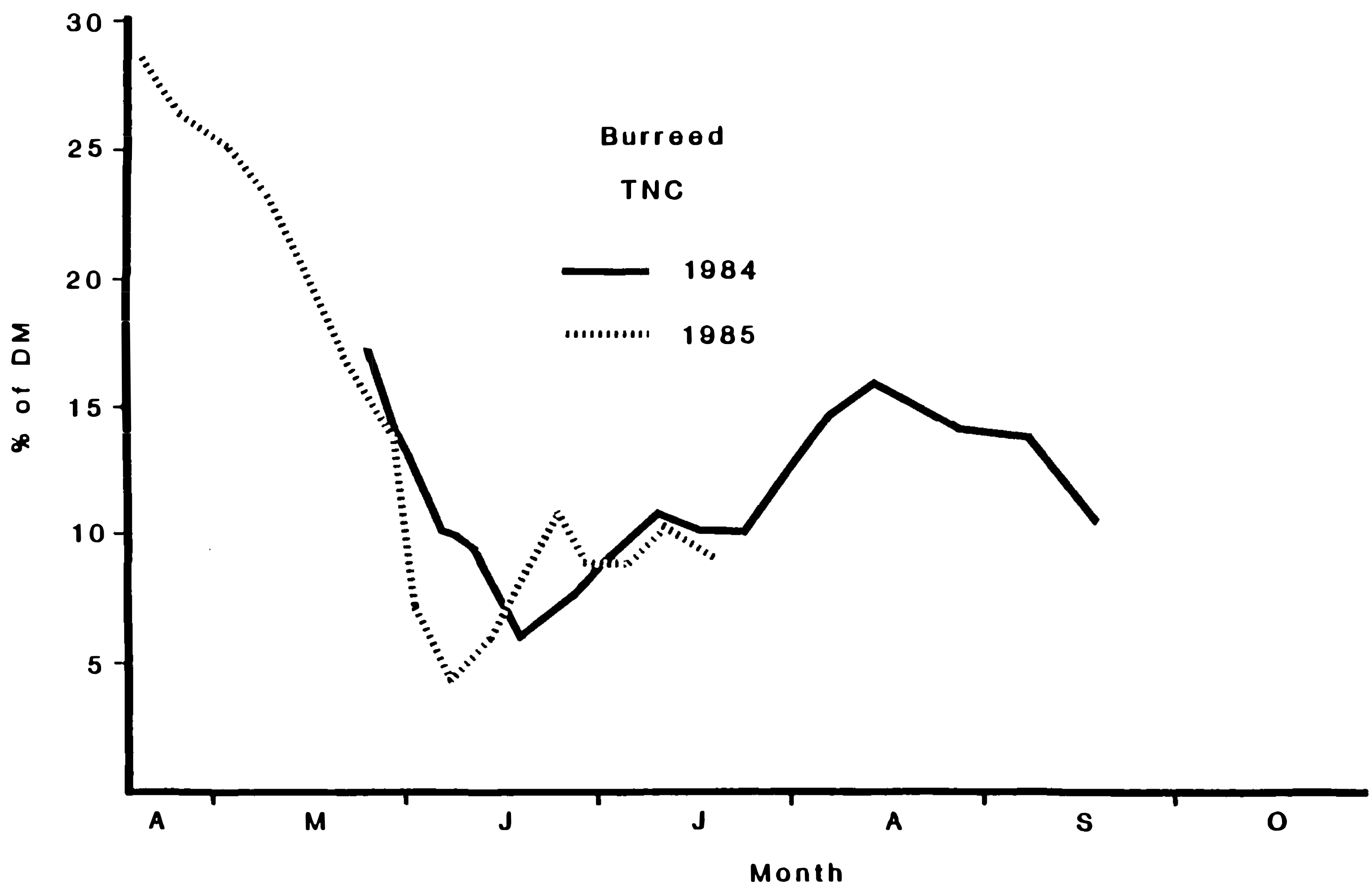

Figure 11. TNC content (% of dry matter) in below ground material of burreed collected in 1984 and 1985.

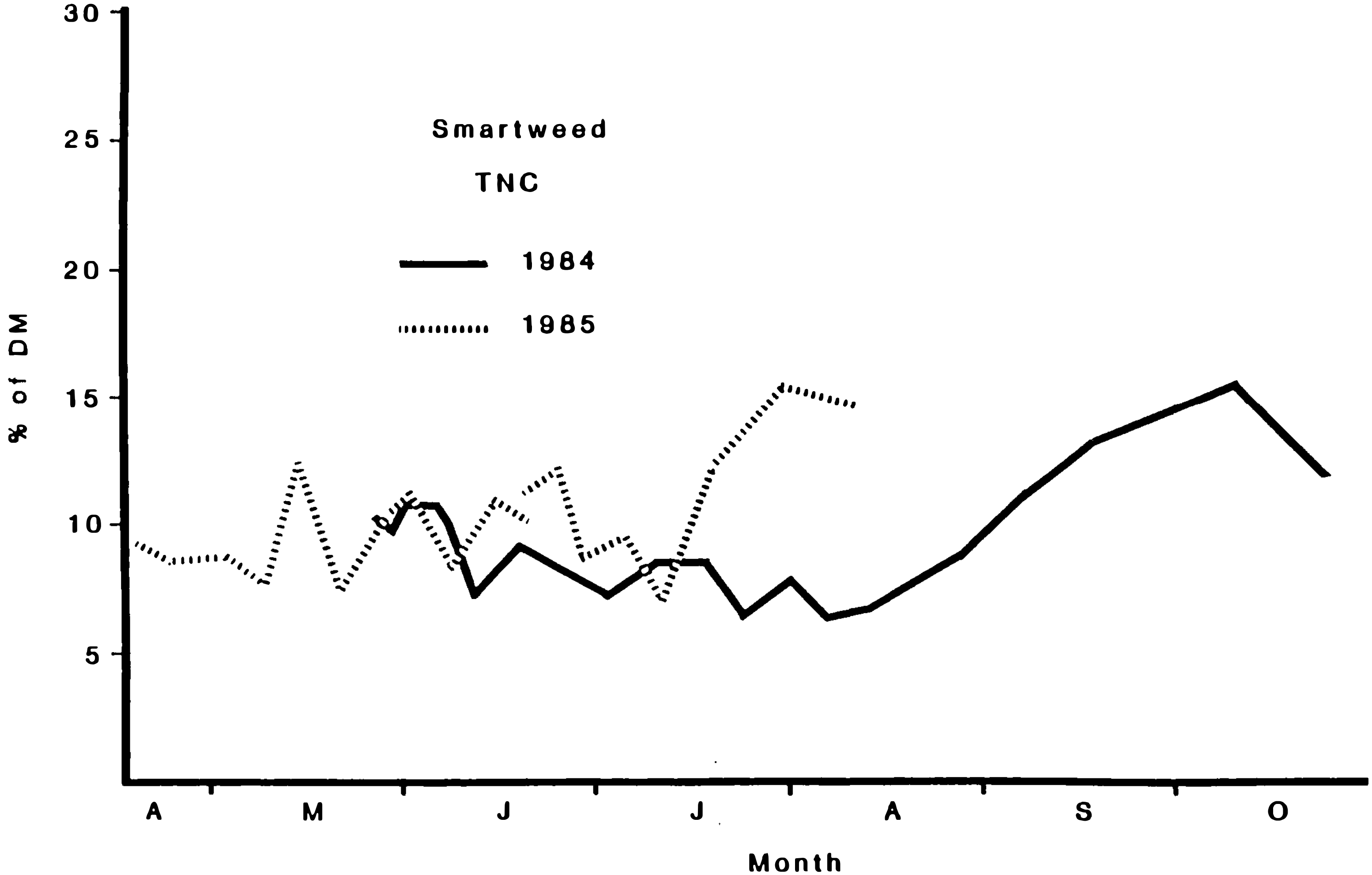

Figure 12. TNC content (% of dry matter) in below ground material of smartweed collected in 1984 and 1985.

The only consistent trend in both years occurred in the latter portion of the collection periods when Dysonchia activity appeared to decrease. No relevant information, then, can be extracted from the TNC data for smartweed.

Forage Potential and Management Implications

This study of wetland plant species forage quality only focused on chemical content and IVDDM. Equally important as chemical and digestibility data are palatability and/or acceptance of the forage by the animal (Mochrie et al. 1981). Although not addressed in the present study, information is available in the literature for 3 of the species studied. Both whitetop (Clarke and Tisdale 1945, Smith 1973a, Looman 1983, Neckles et al. 1985) and slough sedge (Clarke and Tisdale 1945, Hawley et al. 1981a, 1981b, Looman 1983) are palatable for pasturage and hay. The water smartweeds (P. amphibium varieties) are seldom grazed and can be toxic if grazed. However, if mowed and cured they apparently make an excellent light hay without toxic effects (Looman 1983). Published information on the palatability of burreed is apparently lacking; however, Walker and Coupland (1970) and Stewart and Kantrud (1972) have reported evidence that this species is indicative of moderate to heavy grazing. Personal observations by the author in South Dakota support this. In fact, burreed is frequently seen as one of the only species not grazed but standing conspicuous in very heavily grazed pastures suggesting that the species probably increases under grazing due to a low palatability.

CP requirements of cattle vary with energy intake and other factors (Hogan and Weston 1981, NRC 1984). Van Soest (1982) maintains that a CP level of about 8% is the value below which nitrogen, even with salival supplementation via recycling, becomes limiting to microbial production in the rumen. NRC (1984), however, uses a more conservative figure of about 10% CP, even though that publication lists CP (% of dietary dry matter) percentages lower than this for several classes of beef cattle. This apparent discrepancy is accounted for by recycling of N, but the energy content and other nutrients of the feed must also meet their listed values. Otherwise, these low CP values may be insufficient. Those classes for which dietary CP requirement are below 10% are particular classes of mature cows and bulls under certain conditions. However, almost all classes of beef feeder cattle will maintain or gain at very low rates at these low values and some classes (e.g., large-frame steer calves or compensating medium-frame yearling steers, if over about 700 to 800 lbs) will even show good to excellent rates of gain (NRC 1984). CP values between 10 and 14% are in the range typically required for most classes of feeder cattle to make moderate rates of gain at low weights (0.5 to 0.9 kg/day) and high rates of gain at higher weights (0.9 to 1.6 kg/day) (NRC 1984). CP of 14% or greater are typically required for a few classes of breeding cattle, for high rates of gain in a few classes of feeder cattle and for most classes of lactating dairy cattle (NRC 1978).

CP contents of whitetop (Figure 1), slough sedge (Figure 3), and burreed (Figure 5) are only in the higher range (i.e., > 14%, see above) in the very early growing season (prior to 1 June). IVDDM was also good at that time, being in the 50 to 60% range for all 3 species (Figures 2, 4, and 6). However, harvesting for hay at that time of year is impractical for these species. In years with normal to above normal vernal surface water runoff, seasonal wetlands are usually too wet to support mowing equipment. Even if dry enough to mow, yields at that time of the growing season are usually only about 50% or less of the mid-summer maximum in standing crop (see review in Fulton et al. 1986). Therefore, the most efficient method of early season utilization of these species would be by grazing. However, if the pasture unit is exclusively wetland, then consideration must be given to the high moisture content of these species in the early growing season (Tables 8-13). Supplementation to increase dry matter intake would probably be required. If the pasture includes upland, then supplementation may not be necessary.

The 10% to 14% range in CP content that provides adequate protein for most classes of beef cattle occurs in early to mid-June for both whitetop (Figure 1) and slough sedge (Figure 3). Based on the studies compiled by Fulton et al. (1980), yields for both of these species at that time of season should be less than half of what might be expected in mid-summer. The trade-off between quality and quantity of forage is one that farmers have had to deal with for many species (Walton 1983). The utilization of either of these 2 species at this time, however, should be done with caution. The TNC content of below ground material for both was at the lowest levels of the growing season during this same time period (Figures 9 and 10). Harvest of these species in early June may possibly impair their ability to recover and allow for subordinate species in the stand to more effectively compete with them; especially if this harvest regime was repeated for several years. These low TNC levels in the below ground material are a result of the flurry of physiological activity associated with both sexual and vegetative reproduction occurring at that time of year. Waiting until seeds begin to fill for whitetop and after seeds have formed and are about to shatter for slough sedge will help ensure TNC levels are about 2 times greater than the lowest levels. In this study, these events occurred in late June to early July.

Although direct grazing may be practiced at any time, mowing may not be practical (due to soil wetness) until mid-summer in most years anyway. It is just after seed fill that Neckles et al. (1985) recommended whitetop be harvested based on maximum yield. The maximum yield of most wetland stands in the northern prairies probably occurs from mid-June to mid-August for most species (Fulton et al. 1986). If the whitetop in the present study were harvested for hay at that time of year, then CP would be between about 6% to 7% (Figure 1) and IVDDM would be about 40% (Figure 2). Slough sedge would have CP contents of at least a percentage point higher (Figure 3) and IVDDM percentages of about the same to slightly better than whitetop (Figure 4). If cut for hay in mid summer, both of these species would yield a hay that would rate a Grade 5 according to Rohweder et al. (1981). The digestibilities and CP contents of whitetop and slough sedge during midsummer are comparable to many native and domesticated grasses at like stages of maturity and cutting dates in northern latitudes (Heinrichs and Carson 1956, Pritchard et al. 1963, Kamstra 1973, Cogswell and Kamstra 1976). In fact, the data for whitetop and slough sedge compare very closely to digestibility and CP percentages of cool season, temperate grasses at all stages of maturity.

Data for smartweed were confounded by effects of defoliation by insects. Hence, not much can be said about normal smartweed stands based upon this study. Burreed, though, had excellent CP and IVDDM percentages early in the growing season, but very poor IVDDM from midsummer to the end of the growing season. As mentioned earlier, this species appears to be unpalatable to livestock. Therefore, the most relevant information provided by the present study is the TNC data on the below ground material for this species. The very pronounced low TNC values that occurred near the onset of flowering implies that control of this species may be facilitated by a destructive mechanical or herbicidal treatment at that point in phenology.

Conclusions

CP and IVDDM contents of whitetop and slough sedge were comparable to most grasses at similar phenological stages. According to the literature, maximum standing crops of these species should occur in mid summer. At that time, however, the nutritional quality of these 2 species is poor and would make a hay only adequate as a base roughage. If these species are utilized during the approximate periods of tillering and flowering (early June), then there is a possibility of weakening the stands as TNC reserves in below-ground material are at their lowest levels of the season. Harvesting, if possible, or grazing at seed fill for whitetop and just post seed fill for slough sedge will avoid the period of low TNC reserves and yet yield an acceptable quality forage; although maximum yield of biomass may not occur until a few weeks after this time. Burreed, on the other hand, is a species that may be considered for control in seasonal wetlands. Although the data collected in this study show it to be of good nutritional quality in the early growing season, it is apparently unpalatable to livestock. The TNC content of the below ground material of burreed is at its lowest near the onset of flowering. Therefore, control measures should be implemented at that time.

Equations, such as those developed by Rohweder et al. (1981), to estimate digestibility based on chemical constituents are in use in some feed testing labs around the country. Results from the attempts to develop predictive equation in this study show that digestibility estimates for native wetland plant species may be misleading if made using established equations that were developed on tame species.

Chapter 4

IVDDM AND CHEMICAL CONSTITUENTS IN SELECTED SPECIES OF WETLAND PLANTS

Introduction

The number of plant species found in wetland sites is small in comparison to upland sites in native prairie communities in the Prairie Pothole Region (see data in Dix and Smeins 1967, Smeins and Olsen 1970, and Hubbard et al. 1988), and although only 1, 2, or 3 species typically dominate prairie wetland plant stands, several subordinate or understory species are usually present (Fulton et al. 1986). The peripheral temporary wetland is usually more diverse, in terms of species, than the central seasonal wetland in seasonal-wetland-dominated basins (Stewart and Kantrud 1971, 1972, Fulton et al. 1986, Hubbard et al. 1988), despite the fact that only a few species are typically dominant.

Disturbance is a factor that plays a major role in species occurrence and distribution in pothole wetlands (Walker and Coupland 1968, 1970, Walker and Wehrhahn 1971, Stewart and Kantrud 1971, 1972, Millar 1973, 1976, van der Valk and Davis 1976, 1980, van der Valk 1981, 1982). Anthropogenic disturbances are common and important (e.g., mowing, burning, cultivation, etc.), but they all operate within the context of naturally occurring disturbance due to frequent water level changes responding to changing meteorological conditions. Fluctuating water levels in these basins frequently cause plants characteristic of the temporary wetland to move deeper into the basin and invade the seasonal wetland. The reverse situation also frequently occurs. Often there exists a fairly large transition zone between these 2 wetlands (Fulton et al. 1986). In addition, rapid drawdown of open water areas causes bare soil exposure and subsequent germination of drawdown species (typically ubiquitous, weedy, annuals and perennials) or emergent hydrophytes (Stewart and Kantrud 1971); however thick accumulations of litter can inhibit germination (van der Valk 1986). The same relationships exist between and within seasonal and semipermanent wetlands. The upshot of these situations is that, although wetland plant communities can be monotypic and static, they typically have at least some species diversity present and frequently are dynamic.

The number of species that could potentially be found in prairie pothole wetlands is large. Larson (1979) lists 390 species that can occur in North Dakota potholes. However, Stewart and Kantrud (1972) list 45 species characteristic of temporary wetland and 22 that are characteristic of seasonal wetland. Information on nutritional quality of many of these species is lacking. Collection of basic nutritional quality data for these species would be desirable so landowners and managers may at least have some modicum of information upon which to draw when producing and managing forage. In addition, basic information may help future plant breeding programs for wetland species. The objective of this study was to measure the CP and ash content, and the IVDDM of some of the common species found in temporary and seasonal wetlands in eastern South Dakota.

Methods

Plants were harvested by hand at ground level and were subjectively selected. Collections were made at opportune moments during field work for other aspects of this project. All collections were made from public lands throughout Deuel County, South Dakota. In 1984, plants were collected from late August through mid-September. In 1985, collections were made from late June through early August. Plants collected within a stand were combined for a sample. Samples were typically collected at 2 or 3 stands. Notes on phenological stages were recorded. Sample handling and preparation was identical to that described in the Methods section of Chapter 3 and chemical and IVDDM analyses were performed as described in the Methods section of Chapter 2. All samples were analyzed for ash, CP, and IVDDM. Samples collected in 1984 were also analyzed for NDF, ADF with neutral detergent pre-extraction (ADF1), ADF without pre-extraction (ADF2), and ADL.

Results and Discussion

Results of the IVDDM analyses for the alfalfa standards of each run of the procedure in which samples for this study were included are listed in Table 25. Mean deviations from reported values were similar to those listed in Tables 2 and 7. Thus, all IVDDM values presented in this study are similar to those reported previously in this report in that they are probably underestimates, especially at higher digestibilities.

Plant species (names follow Great Plains Flora Association 1986), sample sizes, dates, and range in phenological stages are listed in

Table 25. Mean IVDDM (percent of dry matter at 100°C, n = 3 per run) of alfalfa standards included in each run of selected wetland species from 1984 and 1985.

Run	Low standard (%)	High standard (%)
1	59.0	68.3
2	56.6	70.9
3	57.9	69.9
4	58.1	68.6
5	55.3	66.1
6	55.4	66.9
7	54.8	66.7
Mean:	56.7 (0.6)[a]	68.2 (0.7)
Reported value:	60.0	73.9
Mean deviation from reported value:	-3.3	-5.7

[a]Standard error in parentheses.

Table 26. Since most collections were made earlier in the growing season in 1985, these plants tended to be phenologically younger (typically) than those from 1984. Of the 27 taxa collected, 6 are regarded as indicative of seasonal wetland (Alisma subcordatum, Eleocharis spp., Phalaris arundinacea, Polygonum amphibium var. stipulaceum, Scirpus americanus, and Sium suave), 1 is indicative of semipermanent wetland (S. fluviatilis), 1 is indicative of a fen (saturated water regime) (Scirpus pallidus), and 1 occurs in both seasonal and semipermanent wetland (Drepanocladus spp.) (Stewart and Kantrud 1971, 1972). The remaining 18 species are either indicative of temporary wetlands, or a drawdown situation in seasonal or semipermanent wetlands (Stewart and Kantrud 1971).

Ash, CP, and IVDDM means are listed in Table 27. Based on IVDDM, those species that appear to have poor forage value are Alisma subcordatum, Apocynum cannabinum, Drepanocladus spp., Juncus balticus, Potentilla anserina, and Scirpus fluviatilis. Of these, Drepanocladus is a moss (and hence, is a ground-cover) and would not normally be included in hay, but would be available for grazing. J. balticus is ubiquitous in temporary wetlands and commonly occurs as a codominant. S. fluviatilis frequently occurs as a dominant species in semipermanent wetlands. The other 3 "poor" forages can occur in fairly pure, small patches, but are typically only minor components of the communities. It is interesting to note that several of these "poor" species have fairly high CP percentages for such low corresponding IVDDM values.

Data on S. fluviatilis from Wisconsin (Klopatek 1975) show that CP content for July and August collections are very similar (10.0% and

Table 26. Sample size (n), dates, and phenological stages of temporary and seasonal wetland plant species collected for forage quality analyses.

	1984			1985		
		Range			Range	
Species	n	Date	Stage[a]	n	Date	Stage
Alisma subcordatum	2	8/23	SR-M	-	—	—
Ambrosia spp.	3	8/23-27	A	-	—	—
Apocynum cannabinum	1	8/27	V	2	7/24	V-A
Aster hesperius	4	8/23-30	V-A	3	7/18-29	V-A
Bidens spp.	2	9/7	B-SF	2	7/18-29	V
Calamagrostis canadensis	3	8/23-9/17	M-OM	3	6/28-7/2	A
C. stricta	-	—	—	3	6/28-7/5	A
Carex spp.	3	8/23-9/7	M	2	7/29-8/10	M
Drepanocladus spp.	2	8/23,9/5	—[b]	-	—	—
Eleocharis spp.	3	8/23-30	SS-M	4	7/5-24	SF-M
Helenium autumnale	2	8/23-30	B-SF	2	7/18-24	V-A
Juncus balticus	2	8/23-27	SR-M	2	7/5-8/10	SR-M
Lycopus americanus	2	8/23-9/5	B-SF	2	7/18	V-A
L. asper	3	8/23-27	B-SS	2	7/5-24	V-A
Lysimachia hybrida	3	8/23-9/17	A-M	3	7/18-24	A
Mentha arvensis	3	8/23-30	B-SF	2	7/24-29	B-A
Phalaris arundinacea	-	—	—	2	7/29-8/9	SS-M
Polygonum amphibium var stipulaceum	3	8/23-9/5	A-M	3	7/5-29	V
Potentilla anserina	3	8/23-9/5	V-M[c]	-	—	—
Scirpus americanus	2	8/27	SR-M	2	7/10-29	A
S. fluviatilis	3	8/27-9/7	M[c]	2	7/10-29	A-SR[d]
S. pallidus	-	—	—	2	7/2-5	A-SF
Sium suave	3	8/23	A-SR	2	7/24	A
Spartina pectinata	3	8/23-30	A-SS	3	7/10-24	V-A
Stachys palustris	3	8/23-9/6	A-M	2	7/5-24	V-SF
Teucrium canadense	3	8/23-9/5	B-SF	2	7/5-10	B-A
Vernonia fasciculata	-	—	—	3	7/18-24	V-A

[a]V = vegetative, B = bud, A = anthesis, SF = seed fill, SR = seed ripe, SS = seed shattered, M = mature (early senescence), OM = overmature (over half of material senescent).
[b]Could not assign phenological stages.
[c]No evidence that flowering ever occurred.
[d]Very low percentage of flowering shoots.

Table 27. Mean[a] ash, CP, and IVDDM content of temporary and seasonal wetland plants in 1984 (late summer) and 1985 (mid summer).

	Percent of dry matter[b]					
	Ash		CP		IVDDM	
Species	1984	1985	1984	1985	1984	1985
Alisma subcordatum	8.7	—	12.3	—	26.7	—
Ambrosia spp.	12.7	—	15.7	—	58.6	—
Apocynum cannabinum	7.9	8.0	8.4	12.3	28.3	35.9
Aster hesperius	7.8	8.7	8.8	8.8	44.0	56.1
Bidens spp.	9.4	11.3	13.3	11.7	46.6	48.2
Calamagrostis canadensis	7.2	8.9	7.4	7.4	40.6	43.7
C. stricta	—	6.7	—	5.9	—	37.1
Carex spp.	8.1	8.0	9.2	6.4	42.6	30.4
Drepanocladus spp.	27.0	—	11.6	—	33.3	—
Eleocharis spp.	16.3	13.2	9.0	9.3	31.8	44.9
Helenium autumnale	11.0	13.3	7.5	9.3	53.0	61.0
Juncus balticus	4.6	3.8	9.0	6.8	34.4	27.0
Lycopus americanus	9.5	9.4	15.5	11.4	53.7	59.3
L. asper	10.5	10.0	12.8	9.4	56.5	66.3
Lysimachia hybrida	7.4	6.4	8.5	7.7	38.7	43.7
Mentha arvensis	11.3	9.3	13.3	9.1	51.4	59.4
Phalaris arundinacea	—	12.3	—	6.4	—	33.5
Polygonum amphibium var stipulaceum	6.7	7.0	11.3	10.1	41.4	39.2
Potentilla anserina	8.3	—	9.9	—	30.1	—
Scirpus americanus	18.3	14.4	11.2	10.7	53.7	53.6
S. fluviatilis	11.0	11.1	10.8	9.1	32.5	29.0
S. pallidus	—	7.6	—	6.5	—	47.5
Sium suave	11.4	8.8	10.7	7.5	50.9	49.3
Spartina pectinata	3.8	4.6	4.4	6.2	32.1	40.8
Stachys palustris	8.9	7.5	9.1	7.9	55.6	63.5
Teucrium canadense	10.4	7.4	15.8	11.7	53.6	60.4
Vernonia fasciculata	—	9.8	—	10.5	—	52.4

[a]Sample sizes, dates, and phenological stages listed in Table 25.
[b]Dry matter at 100°C.

9.8% respectively) to those in the present study. However, the ash contents of the Wisconsin plants were several points lower. The relatively high concentrations of dissolved salts in prairie wetlands as compared to wetlands in the more humid eastern U.S. is probably responsible for the higher ash values. The dominant cations in prairie wetland waters (Ca^{2+}, Mg^{2+}, and Na^{+}) (Schmidt 1967, Rozkowski 1968, Stewart and Kantrud 1972, Arndt and Richardson 1986) are passively taken up by plants (Mengel and Kirkby 1982).

Clarke and Tisdale (1945) reported CP values of 15.60%, 12.16%, and 9.18%, and ash values of 8.23%, 5.62%, and 5.14% for J. balticus (reported as J. ater) in the leaf (26 May), flower (23 June), and medium seed (4 August) stages, respectively, in southern prairie Canada. McLean and Tisdale (1960) reported values of 10.66% and 6.40% for CP and 6.29% and 6.11% for ash in J. balticus from British Columbia at the flower and seed stages, respectively. CP values for this species in the present study (Table 27) agree well with data from Canadian studies and ash values appear to be similar. Looman (1983) states this species is palatable and makes light hay with high CP content when young and green, but becomes unpalatable and tough when mature.

The A. subcordatum CP value seems very high in relation to its IVDDM value (Table 27). Data for this species (reported as A. plantago-aquatica) from the U.S.S.R. (Korelyakova 1971, Yakubovskiy and Merezhko 1975) also show this species to be high in CP. Yakubovskiy and Merezhko (1975) reported a season-long mean of 16.3% CP. The very low IVDDM of this species (Table 27) despite its high CP content is probably due to tannins. This is evidenced by the large discrepancy between ADF1 and

ADF2 and the high ADL content (Table 28) (Van Soest 1982). There is, therefore, a high probability that some of the CP, and probably much of the fiber, is tied-up with tannins or lignin and is causing the low IVDDM of Alisma. These same relationships are probably also occurring in A. cannabinum, Drepanocladus spp., and P. anserina (Table 28). No published data on nutritive parameters have been located for these latter 3 species.

Eleven species exhibited mean IVDDM values greater than 50%. For purposes of this discussion, these species will be considered good forage, even though many tame forages can surpass these values if utilized at appropriate times. But most tame grass forages are utilized for hay at about the early head to early seed stages. Digestibilities at this time are in the 50% to 60% range (Pritchard et al. 1963). All of these 11 species had CP percentages that were above 8% (or at least very close to 8%; i.e., H. autumnale and S. suave) (Table 27); eight (Ambrosia spp., L. americanus, L. asper, M. arvensis, S. americanus, S. suave, T. canadense, V. fasciculata) had CP values greater than 10%. For purposes of this discussion, these species will be referred to as very good forages, as these levels of CP are in the range of CP percentages that will make acceptable rates of gain for many classes of beef cattle (see discussion in Chapter 3). For most of these species few published data exist. However, for S. americanus, Clarke and Tisdale (1945) reported an early August ("medium seed" stage) CP value of 9.07% and ash content of 7.9% in southern Saskatchewan and Alberta. While CP values in this study are somewhat higher than Clarke and Tisdale's value, ash content of South Dakota material is much higher.

Table 28. Mean[a] values of detergent fiber and lignin of temporary and seasonal wetland species collected in 1984.

	Percent of dry matter[b]			
Species	NDF	ADF1[c]	ADF2[d]	ADL
Alisma subcordatum	65.6	44.3	49.2	16.9
Ambrosia spp.	45.9	30.9	35.5	7.0
Apocynum cannabinum	35.0	25.5	28.4	10.7
Aster hesperius	55.3	37.2	41.9	8.0
Bidens spp.	55.3	38.2	44.5	8.8
Calamagrostis canadensis	70.1	39.2	43.2	5.7
Carex spp.	71.8	34.7	39.1	3.7
Drepanocladus spp.	55.6	37.8	43.6	11.4
Eleocharis spp.	66.6	39.4	45.2	5.7
Helenium autumnale	46.8	33.2	38.6	6.7
Juncus balticus	77.5	35.1	36.8	3.0
Lycopus americanus	51.3	30.3	35.0	10.3
L. asper	39.0	25.8	30.6	5.7
Lysimachia hybrida	47.1	32.9	37.4	9.9
Mentha arvensis	42.1	28.0	33.6	8.1
Polygonum amphibium var *stipulaceum*	46.2	30.3	29.2	11.0
Potentilla anserina	31.8	22.4	28.3	6.4
Scirpus americanus	60.5	34.0	39.4	3.6
S. fluviatilis	71.5	37.2	40.0	6.0
Sium suave	54.2	36.4	43.7	9.0
Spartina pectinata	78.8	45.9	48.4	8.1
Stachys palustris	49.0	32.5	39.0	7.8
Teucrium canadense	50.5	30.9	36.6	8.6

[a]Sample sizes, dates, and phenological stages listed in Table 25.
[b]Dry matter at 100°C.
[c]Pre-extracted with neutral detergent solution.
[d]Not pre-extracted with neutral detergent solution.

As discussed previously, high ash values could be due to a high mineral content of the water. Marten and Andersen (1975) reported CP and IVDDM values for Ambrosia artimisiifolia of 25.1% and 73.0%, respectively, in Minnesota in mid-July (late bud stage). They also reported that A. artimisiifolia was palatable to some sheep but not to others. The large difference in CP values between the Ambrosia of this study versus the Minnesota Ambrosia could be due to species differences (it is unfortunate that species recognition was neglected in this study) or to site fertility. The soil of the Minnesota study was N fertilized. On the other hand, the wetlands in this study could possibly be N limited. Although N reduction has not been studied in temporary or seasonal prairie wetland soils (Hubbard 1988), the high organic matter content and the frequent wetting and drying cycles that occur in these soils are ideal conditions for N reduction to take place (Mohanty and Dash 1982, Ponnamperuma 1984). Numerous studies have demonstrated increased CP content of forages with increasing N fertility (see Mengel and Kirkby 1982). The very high IVDDM content reported by Marten and Andersen (1975) for Ambrosia could be due to the high CP content as in many species digestibility is correlated with CP (Oh et al. 1966, Hubbard et al. 1987, Chapter 3 of this study).

Although Ambrosia was the only taxa of the 8 "very good" forages for which palatability information could be found, personnel observations of the author suggest that Lycopus asper and Vernonia fasciculata may possibly be unpalatable. L. asper has a very strong odor, similar to turpentine, which suggests the presence of aromatic secondary compounds that could possibly affect palatability. L.

americanus, on the other hand, does not have this odor. V. fasciculata has been observed in fairly heavily utilized pastures as an untouched species — fairly convincing evidence that it may be unpalatable.

Of the 11 species that have been referred to as "good" or "very good", Aster hesperius is the only one that the author has personally observed to occasionally comprise an apparently large portion of the biomass in seasonal or temporary wetlands in eastern South Dakota. However, many of the other species, in addition to being frequent understory species can occasionally be found in relatively pure "patches", i.e., Ambrosia spp., L. americana, L. asper, M. arvensis, S. americanus, S. palustris, T. canadense. The remaining species typically occur as scattered individuals.

Of the 10 species not yet discussed, C. canadensis, C. stricta, Carex spp., Eleocharis spp., P. arundinacea, P. a. stipulaceum, and S. pectinata can all be found as dominants or codominants in temporary or seasonal wetland. Rather even mixtures of Carex spp., Eleocharis spp., S. pectinata, either species of Calamagrostis, and J. balticus frequently occur in temporary wetland in native prairie situations. P. arundinacea, Eleocharis spp., and P. a. stipulaceum can all either dominate or codominate seasonal wetland. Of the remaining species, Bidens spp. are common but typically not dominant unless drawdown exposes bare soil, L. hybrida occurs as scattered individuals in temporary wetland, and S. pallidus occurs as scattered individuals in fens (Stewart and Kantrud 1971) but also frequently in the peripheral temporary wetland in either seasonal-wetland-dominated or semipermanent-wetland-dominated basins.

Bidens spp. had high CP content, and IVDDM values almost as high as the "good" species. _L. hybrida_ had marginal CP content and low IVDDM (Table 27). _S. pallidus_ is interesting in that, although it had very low CP content (6.5%), the IVDDM value was 47.5%. Those species that typically can dominate or codominate have either low CP or IVDDM or both; at least during the mid to late periods of collection used in this study (Table 26). Data reported by Johnston and Bezeau (1962) for _C. stricta_ (reported as _C. inexpansa)_ showed much higher CP values (9.78%) at comparable phenology in southwest Alberta. From central Alberta (near Edmonton), Corns and Schraa (1962) reported a first cutting CP content at anthesis for _C. canadensis_ of 9.4%. However, the CP content reported by Clarke and Tisdale (1945) (reported as _C. inexpansa)_ from southern Alberta and Saskatchewan was only 7.10% at flowering, but still higher than the value for the present study (Table 27). The data for _C. canadensis_ show that CP and IVDDM were similar for either the late summer (1984) or mid-summer (1985) collections (Table 27). Both ash and CP content were higher in _C. canadensis_ than in _C. stricta_ at anthesis in 1985. Clarke and Tisdale (1945) also reported a higher CP content for _C. canadensis_ (8.26%) at flowering than for _C. stricta._ Looman (1983) stated that _C. stricta_ (referred to as _C. inexpansa)_ is more palatable than _C. canadensis,_ but cautioned that there exists conflicting reports on the palatability of the latter and that the earlier in the season that both species are utilized, the better cattle will accept them.

S. pectinata had low IVDDM values and very low CP content in both years (Table 27). Even when the plants were in the vegetative to anthesis stages (1985), CP content averaged only 6.2%. Cattle fed a hay comprised mostly of this species, even if cut at flowering, would need protein supplementation. Nicholson and Langille (1965) also found low CP contents and low digestibility of this species in Nova Scotia at normal times of harvest (head to seed stages). However, very early in the growing season (leaf stage; mid-June) it had an apparent digestibility of 61.9% and a CP content of 13.8%. Looman (1983) stated this grass is seldom grazed when other forage is available.

The Carex spp., even though collections consisted of mature plants in both years, had variable CP and IVDDM content between years (Table 27). This could be due either to site fertility differences or to species composition. The 1984 collections averaged 9.2% CP, which is high enough for maintenance, but in 1985 they averaged only 6.4% CP. This latter value indicates that a CP deficiency would occur on hay from these species if not supplemented. The species comprising these samples were primarily C. lanuginosa and C. tetanica; however, C. sartwellii and C. praegracilis were probably also present in the samples. Few data exist for these caricies. Knight et al. (1908) reports a mid-August CP content of 12.62% for C. lanuginosa from Wyoming and McLean and Tisdale (1960) report CP values for C. praegracilis of 10.45%, 7.84%, and 3.62% for the flower, seed, and weathered stages in southern British Columbia.

P. arundinacea had both low CP content and low IVDDM values in the 1985 collections (Table 27). This should be expected as mature plants of this species are well known to be low in palatability and digestibility when mature (Smith 1981b). Low palatabilities are related to alkaloid content (Marten et al. 1973). The CP content found in this study was lower than those for comparable stages found in much of the literature since those studies all were conducted on N fertilized stands using domestic cultivars (e.g., Wolf 1967, Myhr et al. 1978, Saibro et al. 1978). However, data reported by Klopatek (1975) in Wisconsin show the species to be poor in CP (all values less than 5.75% after 15 July). Clarke and Tisdale (1945) reported a value of 9.77% CP in southern prairie Canada at flowering (28 July).

The levels of CP and IVDOM in P. a. stipulaceum (Table 27) are very similar to those of P. a. emersum (Figures 7 and 8). The NDF, ADF1, and ADF2 content of this species (Table 28) were a few percentage points lower than for P. a. emersum (Table 14) at comparable dates, but ADL values were similar. The lower detergent fiber fractions in P. a. stipulaceum may be expected since this species tends to have a more recumbent habit, often with the majority of the stem immersed. P. a. emersum, on the other hand, is more upright with the majority of the stem emersed thus requiring a higher percentage of cell wall material for structural support.

Conclusions

Although several species characteristic of temporary and seasonal wetlands would make rather poor forage, almost one-half of the species studied would make acceptable forage during the mid to late summer period. Palatability of most of these species, however, is not known. Most of these species are forbs that are subordinate components of the communities. Most of the species that are dominant in these wetlands make only mediocre to poor forage in mid to late summer. It is common practice in South Dakota to wait until late summer to mow wetlands for hay. The data presented in this Chapter reinforce a conclusion of Chapter 3, i.e., that seasonal-wetland-dominated basins should be mowed earlier in the growing season than is normally practiced in order to optimize forage quality.

Chapter 5

A STUDY ON THE EFFECT OF MOWING ON WHITETOP AND SLOUGH SEDGE

Introduction

Effects of mowing on seasonal wetland vegetation have not been evaluated in the southern portion of the Prairie Pothole Region. In Canada and North Dakota, whitetop is apparently favored by moderately saline water and a burning or mowing regime (Dix and Smeins 1967, Walker and Coupland 1968, Stewart and Kantrud 1972, Smith 1973a, 1973b, Neckles et al. 1986), and slough sedge has been reported by Walker and Coupland (1968) to be out-competed by whitetop in situations where they occur together under a mowing regime. Walker and Coupland (1970) stated that in fresh water, and if left undisturbed, slough sedge will out-compete other species. Millar (1973) provided evidence that grazing can reduce slough sedge but found no evidence that mowing reduced slough sedge vitality to allow whitetop to out-compete it as stated by Walker and Coupland (1968).

Stewart and Kantrud (1972) maintained that, in fresh seasonal wetland, slough sedge is the predominant species if undisturbed; both slough sedge and whitetop can predominate if mowed; and slough sedge and giant mannagrass (<u>Glyceria grandis</u>) predominate if lightly grazed. With heavier grazing pressure, though, slough sedge drops out. In slightly brackish seasonal wetland, Stewart and Kantrud (1972) list slough sedge and whitetop as predominating in undisturbed situations; whitetop only in mowed situations; slough sedge only in lightly grazed wetland; and slough sedge and spike rush (*Eleocharis palustris*) in moderately grazed wetland. Neither slough sedge nor whitetop are listed as predominant species in more intense land-use situations in slightly brackish seasonal wetland. In moderately brackish seasonal wetland these authors list whitetop as the predominant species occurring in both undisturbed and mowed situations. Under any grazing pressure in moderately brackish seasonal wetland, neither whitetop nor slough sedge are listed as predominant by Stewart and Kantrud (1972).

The objective of this experiment was to evaluate the species composition and nutritional quality of whitetop and slough sedge stands after 2 years of mowing treatments.

Methods

Sites (4, 5, and 6) used for late-season standing crop estimations in 1983 (Chapter 2), were also used as study sites in this investigation. In 1983, Site 4 was totally dominated by slough sedge; Site 6 was dominated by whitetop, but had slough sedge as a subdominant; and Site 5 was codominated, equally, by both species (Table 1). Five meter wide strips were delineated at each site and orientated across the "width" of each site. A coin was tossed to decide which end strip at each site was to be a mowed or a control treatment. Thereafter, the treatments were alternated among the strips at each site. This arrangement resulted in 3 strips each of both treatments at Sites 4 and 5, and 5 strips each at Site 6. All Sites were mowed on 7 November 1983 by personnel from the S.D. Department of Game, Fish, and Parks, using a small tractor with a rotary mower. Usually, more than 1 pass over the strips was necessary. A cycle-bar mower was tried, unsuccessfully, prior to using the rotary mower. The vegetation proved too dense to be cut by the cycle-bar. The cut vegetation was to be removed from the plots by manually raking. But snowfall within 1 week of mowing precluded raking.

All 3 wetlands ponded the following spring. Sites were visited weekly to monitor water levels in 1984. Treatments were to be sampled in that year as soon as the sites were dry enough to support a tractor. Then, plots were to be clipped and the mowed treatments cut in order to repeat sampling in 1985. However, in 1984 the sites never dried-out to the point at which they could support machinery. The lowest observed water levels occurred at Site 4 on 5 September (landward side dry, but lower elevations ponded less than 6 cm deep), at Site 5 on 30 August (lower elevations had up to 12 cm of water, but higher elevations dry), and at Site 6 on 6 September (most all portions under at least 11 cm of water but a few portions were just saturated). When it became apparent that the sites were not going to be dry enough to mow at a time that would reasonably approximate a normal haying date, it was decided to sample the vegetation and terminate the experiment.

Two transects were established within each mowed and control strip at each site. All transects ran lengthwise through the strips and each pair was situated 5 m apart with each being 2.5 m in from the edges of the strips. The total length of both transects within each treatment strip was used for selection of that strip's complement of sample plots. Each 1 m interval along the transects in each strip was used a point from which to select from. Once a point was selected from a random numbers table, a coin was tossed to determine if the sample plot should be collected from the right or left side of the transect. Once selected, a plot was laid down 1 m away from the transect. A steel frame, 0.5 m x 1.0 m, was used for plot harvesting. All vegetation within the frame was clipped at the top of the fallen litter layer, i.e., the apparent substrate surface. Harvested material was placed in plastic bags and, upon return to the lab, was manually sorted by species. Dead material that was detached from green material was regarded as litter and grouped as one component, regardless of species. Procedures for air-drying, oven-drying, and grinding were described in the methods section of Chapter 3.

Eighteen plots were harvested in each of the mowed and control treatments at Sites 4 and 6. Only 10 plots were harvested in each treatment at Site 5. Plots for each treatment at each site were distributed proportionately among the strips according to strip size. Each strip, within each treatment at each site, was treated as a replication for purposes of statistical analyses. The yield between the mowed and control treatments at each site was compared using a nested analysis of variance (NESTED procedure, modified for unequal sample size, according to S.A.S. 1985). Plots were harvested on 11 September 1984 at Site 5, on 13-14 September at Site 4 and on 27 September through 4 October at Site 6.

To compare nutritional quality of major species (whitetop, slough sedge, and "litter") between treatments at each site, a restricted random sample of plots containing the species was selected. Restrictions were: (1) a plot needed at least 8 g of oven-dry material of the species being tested in order to be eligible for selection, and

(2) a maximum of 50% of the eligible plots would be selected from within each replication, but a minimum of 2 plots would be used from each replication of each treatment. The plots used for comparisons of each species were selected independently from each other. Selected samples were analyzed for ash, CP, and IVDDM as described in the methods section of Chapter 2. Nested analysis of variance was used to compare treatments.

Results and Discussion

Significantly greater biomass occurred on the control treatment for both standing crop ($P<0.05$) and standing litter ($P<0.01$) at Site 4 (Table 29). This site was dominated exclusively by slough sedge and in the deeper portions of the mowed replications, the sedge had died-out almost completely. In the shallower portions of the mowed replications, the sedge appeared to be just as vigorous as in the control replications. In fact, of the top 10 yielding plots at Site 4, 4 were in the shallow portions of the mowed replications. The highest yielding plot of all occurred in the shallow portion of a mowed replication (1336.4 $g \cdot m^{-2}$).

One possible explanation for the die-off of slough sedge in deeper portions of the wetland could be that shoots had insufficient oxygen for growth to the water surface. Flooding of cut cattail (<u>Typha</u> spp.) stems has been used to control it by marsh managers for years (e.g., Nelson and Deitz 1966, Weller 1975). Cattail death results from a lack of oxygen which is normally supplied to the roots and rhizomes via the previous year's dead shoots (Sale and Wetzel 1983). However, this explanation does not appear satisfactory because: (1) no shoots

Table 29. Comparison of late summer standing crops and standing litter in mowed versus control treatments at 3 sites in Deuel County, South Dakota, in 1984 (additional statistics are listed in Appendix A).

		Mean standing crop ($g.m^{-2}$)		Mean standing litter ($g \cdot m^{-2}$)	
Site	n	Mowed	Control	Mowed	Control
4	18	402.8	716.4*	20.8	84.6**
5	10	824.4	681.2*	45.4	77.2
6	18,17[a]	489.8	615.4	36.8	87.2**

*Significant difference between mowed and control at $p<0.05$; nested ANOVA.

**Significant difference between mowed and control at $p<0.01$; nested ANOVA.

[a]n = 18 for mowed and n = 17 for control.

were observed that had attempted to grow but died before reaching the surface, and (2) there was a clean break between mowed and control replications in the deeper water. This latter observation is relevant because if oxygen starvation of rhizomes was the cause of death, then along the edges of the mowed replications one would expect some shoot emergence due to oxygen being supplied by the adjacent shoots on the control plots. From the experience of sampling rhizome material in previous work (Chapter 3), it would seem reasonable to assume that many shoots within about 1 m of the boundary should arise from rhizomes attached to aerial shoots in the control strips.

A more plausible explanation is that slough sedge primordia died from effects of toxic compounds that were produced from anoxic conditions caused by the large volume of dense, chopped organic matter. Sulfide is a most probable toxic compound (Goodman and Williams 1961, Ingold and Havill 1984). However, manganese or a myriad of organic decomposition products could be the cause (Ponnamperuma 1984). Although wetland plants have evolved various strategies to cope with toxic effects of anaerobiosis (Hutchinson 1975), the large amount of fairly dense, chopped, organic matter probably overwhelmed the system by facilitating development of intense microbial activity. Ordinarily, under undisturbed conditions, much of the litter would be dispersed loosely throughout the water column and microbial activity would not be so intense at the soil surface.

The mean standing crop of the mowed treatment at Site 6 was also lower than that of the controls, but this was not statistically significant (Table 29). Variability in the data was tremendous. Most of the variance in the nested ANOVA was due to error (ca. 92%, data not shown). The whitetop at Site 6 did not show the drastic response to mowing that the sedge exhibited at Site 4. On the other hand, whitetop in mowed treatments appeared to be noticeably taller and less subject to lodging than plants in controls. Although mowed treatment plants appeared more robust, there were nonvegetated stripes within the mowed replications that corresponded to the wheel tracks left by the tractor the previous autumn. Many of the random plots fell across these "wheel tracks" and probably accounts for the low mean standing crop. Those plots that did not fall across a wheel track surely contributed to the large variance and lack of statistical significance.

Cause of whitetop disappearance in wheel tracks could be the same as what possibly caused the sedge to die, i.e., build-up of toxic, anaerobically-produced compounds. However, it is possible that dead stripes may have been produced by mechanical injury to below-ground organs. Whitetop rhizomes are very fragile, easily crushed with the thumb and forefinger, and occur very close to the substrate surface. Accumulation of litter on the soil surface in this idle wetland could cause surface sediments to be soft allowing the tractor tires to crush the rhizomes. The author has personally noted 2 other whitetop marshes in Deuel County, located on private land, that were mowed for hay in 1983 that also exhibited these dead wheel tracks in 1984. Although the mowing history of these 2 wetlands is unknown, it is assumed that they have not been mowed for several years. These dead stripes have not been reported by other workers for whitetop marshes that are frequently mowed (Smith 1973a, Neckles et al. 1985).

The mean standing crop at Site 5 was significantly higher ($P<0.05$) on the mowed treatment than on the controls (Table 29). This result, although inconsistent with the results at Sites 4 and 6, is consistent with what one would expect based on the findings of Smith (1973a). In his study, it was found that whitetop yielded much higher on mowed or burned wetlands than on grazed or idle wetlands. Site 5, however, was not dominated solely by whitetop. Whitetop was codominant with slough sedge. Of the total above ground standing crop, including litter, whitetop comprised 51.6% and 57.6% of the biomass on the control and mowed treatments, respectively. Slough sedge comprised 37.5% and 34.3%, respectively, of the total above ground biomass on the control and mowed treatments. Of the above ground biomass present in the fall of 1983, slough sedge comprised 35.7% of it at this site (Table 1). Although it appears that whitetop comprised a much higher proportion of the biomass on both treatments in 1984, standing litter in these September collections was only 8.9% on controls and 4.4% on mowed treatments of the total above ground biomass. This compares with 25.7% in late October in 1983. It appears neither whitetop nor slough sedge can be implicated as being solely responsible for the increase in yield on the mowed treatment.

Mean standing litter was higher at all sites on the control treatments than on the mowed treatments (Table 29) and was statistically significant at Sites 4 and 6 ($P<0.01$). Theoretically, there should have been no standing litter at all on the mowed treatments. But since any brown material that was not attached to a green plant in the collections was treated as litter, this was to be expected. The first leaves of most grasses and sedges die early in the growing season.

IVDDM data for the high and low alfalfa standards are listed in Table 30, and are closer to the reported values than those in previous chapters (Tables 2, 7, and 25). Mean values of ash, CP, and IVDDM for slough sedge, whitetop, and standing litter on both treatments at all sites are listed in Table 31. Significant differences occurred only for whitetop CP at Sites 5 and 6 ($P<0.05$). The relationship between whitetop CP content at these sites was reversed. This reversal of relationships does not allow any conclusions to be drawn. It should be pointed out that there were significant differences among replications in the nested ANOVAs (data not shown) for ash and CP in sedge at Site 4, for IVDDM in sedge at Site 5, and for IVDDM in litter, CP in sedge, and ash in whitetop at Site 6. This exercise serves to point out that site to site variability in these nutritional parameters is greater than variability between treatments. The data in Table 31 do serve to reinforce the conclusions of Chapter 2, viz, whitetop harvested late in the growing season is a very poor forage, while slough sedge quality can be much better. Although slough sedge IVDDM was low at all sites and CP was deficient at Site 5, the CP content at Site 6 was at least adequate for maintenance and at Site 4 it was almost good enough for some beef cattle classes to make gains.

Conclusions

The original objectives for this part of the project could not be met due to many interacting factors. However, the data collected do serve to reinforce the conclusions of Chapter 2 insofar as they show

Table 30. Mean IVDDM (percent of dry matter at 100°C, n = 3 per run) of alfalfa standards included in each run of samples for the mowing study.

Run	Low standard (%)	High standard (%)
1	57.9	69.9
2	58.7	69.3
3	54.9	70.3
4	57.2	70.5
Mean:	57.2 (0.8)[a]	70.0 (0.3)
Reported value:	60.0	73.9
Mean deviation from reported value:	-2.8	-3.9

[a]Standard error in parentheses.

Table 31. Comparison of IVDDM, ash, and CP content of species from mowed (M) and control (C) treatments at Sites 4, 5, and 6 in the late summer of 1984[a] (additional statistics are listed in Appendix B).

			Mean (% of dry matter)					
			Ash		CP		IVDDM	
Site	Species	n	M	C	M	C	M	C
4	Slough sedge	9	8.8	7.5	9.3	9.0	46.4	42.9
4	Litter	9	21.3	16.2	17.0	16.3	21.5	21.7
5	Slough sedge	7	6.8	6.6	6.4	6.5	45.1	38.4
5	Whitetop	7	7.2	7.3	5.9	6.5*	31.9	32.8
5	Litter	6,7[b]	20.9	19.8	9.8	9.4	31.3	30.4
6	Slough sedge	8	8.4	8.5	8.3	7.8	40.3	39.3
6	Whitetop	11	8.5	7.2	6.9	5.8*	37.8	33.3
6	Litter	11	15.2	13.2	13.0	11.8	21.0	20.0

*Control mean is significantly different ($p<0.05$) from mowed mean for this constituent.

[a]Mowed treatments were cut in 1983. In 1984, Site 4 was sampled from September 13-14, Site 5 was sampled on September 11, and Site 6 was sampled from September 27 through October 4.

[b]Sample sizes for mowed vs. control, respectively.

that whitetop is a very poor forage late in the growing season and slough sedge may make an acceptable low grade hay. Also, the results of this study suggest that slough sedge may be more susceptible to anaerobically induced toxicities than whitetop.

Chapter 6

STANDING CROPS AND NUTRITIONAL QUALITY OF SEASONAL-WETLAND-DOMINATED BASINS AND ASSOCIATED UPLANDS IN NATIVE MIXED-GRASS PRAIRIE

Introduction

In Chapter 2, it was demonstrated that seasonal-wetland-dominated basins can yield large quantities of vegetation and some quasi-comparisons were made with published values of yields of tame and managed forages. In several sections of this report, quasi-comparisons have also been made of various measurements of nutritional quality between forage produced in seasonal wetlands and uplands. In order to properly put the quantity and quality of seasonal wetland vegetation in perspective, seasonal-wetland-dominated basins should be compared with their associated uplands in native plant communities. The objective of this study was to compare the above-ground standing crop and its CP and IVDDM content in 2 seasonal-wetland-dominated basins with their adjacent upland plant communities.

Methods

The wetlands at Sites 1 and 2 (Chapter 2) were selected for this study. They are both seasonal-wetland-dominated basins dominated by slough sedge in the seasonal wetland portion, and are located within a few hundred meters of each other. Permanent transects were established in the spring of 1985 at 4 locations at each site.

One circular (actually polygonal) transect was established in the emergent seasonal wetland area. This transect (the seasonal wetland, or

S.W. transect) was established by placing steel fence posts in the marsh such that lines connecting the posts would approximately follow the center of the seasonal emergent wetland "zone". The very center of Site 1 experienced a die-off of vegetation due to ponding that occurred virtually throughout the entire growing season of 1984. Ponding also occurred during the entire growing season at Site 2, but the die-off in the center was only partial. The S.W. transect was situated to avoid this central open zone. The peripheral temporary wetland at each site also had a circular (polygonal) transect situated through its center. The band of temporary wetland indicators was narrow and overlapped with the seasonal wetland indicators substantially. Therefore, the temporary wetland (T.W.) transect had some seasonal wetland species present. Total lengths of seasonal wetland transects were 93 m and 100 m at Sites 1 and 2, respectively. Temporary wetland transects totalled 130 m and 135 m, respectively, at sites 1 and 2.

A split "upland-upper" (U.U.) transect was situated at an approximately constant elevation on either side of the wetland. This transect was "fit" to the landscape at the highest elevation, upslope from the wetland, at which a usable length of transect could be obtained at an elevation of about ±0.3 m. At both sites, this meant that the transect had to be discontinuous. A second upland transect, an "upland-lower" (U.L.) transect, was situated at an elevation exactly half-way between the U.U. and T.W. transects at both sites. This transect was also discontinuous at both locations. Total lengths of the U.U. transects were 64 m at Site 1 and 125 m at Site 2. Total lengths of the U.L. transects were 66 m and 89 m at Sites 1 and 2, respectively.

At each sampling session, 6 plots, each measuring 0.35 m x 0.70 m, were harvested along each of the 4 transects at each site. The 6 plots on each transect were picked using a random numbers chart. Each 1 m interval on a transect was a potential plot location. When a number was selected, a coin would be tossed to determine if the plot would be placed to the right or left of the transect. Once a plot was selected, it could not be used again. All plots were clipped manually at ground level using a tubular P.V.C. pipe frame as a guide. Material from each plot was placed in its own bag for transport to the lab where the contents were separated into (1) current season's growth and (2) litter components. Litter was discarded. The current season's growth from each plot was air-dried and oven-dried according to the procedures described in Chapter 3. After weighing, oven-dry material was ground (1 mm screen) and thoroughly mixed. Aliquots (about 1 l volume) of each plots material were then saved for CP and IVDDM analyses. These analyses followed the procedure given in Chapter 2.

In order to document the species composition of the transects, canopy coverage estimates were made for each species occurring in each plot prior to clipping. Canopy coverage estimates were made according to Daubenmire (1959) but actual percentages were estimated, rather than using the cover classes the author suggests, and plot size was larger.

Plots were clipped at each site every 3 weeks for a total of 8 clipping sessions per site throughout the growing season. The first session commenced on 17 May 1985 at Site 1 and on 22 May 1985 at Site 2. The last clipping session at Site 1 began on 8 October 1985, and on 14 October 1985 at Site 2. Yields, CP content, and IVDDM were tested between transects at each site using analysis of variance with a 4 x 8 factorial arrangement (transects x date) of the data.

Results and Discussion

Species frequencies and season-long means of canopy coverage estimates are listed in Table 32 for Site 1 and Table 33 for Site 2. Based on mean canopy coverage, Kentucky bluegrass (Poa pratensis) was the dominant on uplands at both sites. The next most prevalent grass species on the uplands was little bluestem (Andropogon scoparius) at both sites. The dominant forbs at Site 1 were 2 species of goldenrod (Solidago canadensis and S. rigida) while at Site 2, S. canadensis was the dominant forb based on canopy coverage. Although many species of grasses were common on uplands at both sites (high frequencies of occurrence), none approached Kentucky bluegrass, or even little bluestem, in terms of coverage. Dominant species on the S.W. transects were slough sedge (Carex atherodes) and smartweed (Polygonum amphibium var. emersum) at Site 1, and slough sedge and burreed (Sparganium eurycarpum) at Site 2. The dominant taxa on the T.W. transects was Carex spp. at both sites. The subdominants at both sites were also the same on the T.W. transects: northern reedgrass (Calamagrostis stricta), slough sedge, spikerush (Eleocharis palustris), and prairie cordgrass (Spartina pectinata).

The season-long means of above ground standing crops on each transect at both sites are listed in Table 34. These numbers are much lower than the peak standing crops on all transects due to the influence of the early season data. At Site 1, both wetland transects significantly ($P<0.05$) out-yielded the upland transects by about 2 to 1.

Table 32. Growing season-long means of canopy coverage estimates (C) (percent) and frequencies of occurrence (F) (number of plots occurred in) of species at Site 1 (n = 48).

	Wetland				Upland			
Transect[a]:	Seasonal		Temporary		Lower		Upper	
Species	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)
Achillea millefolium	0	0	0	0	29	2	24	1
Agropyron smithii	0	0	1	tr	25	2	27	2
A. trachycaulum	0	0	0	0	35	5	36	4
Allium spp.	0	0	0	0	1	tr	0	0
Ambrosia psilostachya	0	0	0	0	3	tr	0	0
Andropogon gerardii	0	0	0	0	11	4	15	4
A. scoparius	0	0	0	0	41	19	37	19
Anemone cylindrica	0	0	0	0	9	1	9	tr
A. patans	0	0	0	0	23	1	29	2
Apocynum cannabinum	0	0	2	tr	0	0	0	0
Artemisia ludoviciana	0	0	0	0	1	tr	1	tr
Astragalus spp.	0	0	0	0	1	tr	4	1
A. adsurgens	0	0	0	0	1	tr	0	0
A. agrestis	0	0	0	0	0	0	1	tr
Asclepias spp.	0	0	0	0	5	tr	0	0
A. ovalifolia	0	0	0	0	1	tr	0	0
A. verticillata	0	0	0	0	4	tr	1	tr
Aster ericoides	0	0	1	tr	29	5	35	7
A. hesperius	0	0	22	5	0	0	0	0
A. sericeus	0	0	0	0	1	tr	1	tr
Beckmannia syzigachne	1	tr	0	0	0	0	0	0
Bidens frondosa	0	0	4	tr	0	0	0	0
Bouteloua curtipendula	0	0	0	0	36	11	38	8
B. gracilis	0	0	0	0	0	0	1	tr
Bromus inermis	0	0	0	0	1	tr	0	0
Calamagrostis canadensis	4	1	14	7	0	0	0	0
C. stricta	1	tr	30	16	0	0	0	0
Carex spp.	7	1	47	69	32	6	11	1
C. atherodes	48	81	19	19	0	0	0	0
Cirsium arvense	0	0	0	0	4	tr	2	tr
Dalea purpurea	0	0	0	0	2	tr	1	tr
Dicanthelium leibergii	0	0	0	0	3	tr	2	tr
Eleocharis palustris	23	4	46	28	0	0	0	0
Geum triflorum	0	0	0	0	2	tr	3	tr
Glycyrrhiza lepidota	0	0	1	tr	0	0	0	0
Heuchera richardsonii	0	0	0	0	1	tr	1	tr
Hierochloe odorata	0	0	1	tr	0	0	0	0

Table 32 Cont.

	Wetland				Upland			
Transect:	Seasonal		Temporary		Lower		Upper	
Species	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)
Juncus balticus	0	0	5	3	0	0	0	0
Koeleria pyramidata	0	0	0	0	4	tr	3	tr
Lathyrus palustris	0	0	5	1	0	0	0	0
Lithospermum canescens	0	0	0	0	5	tr	11	tr
Lycopus asper	3	tr	27	3	0	0	0	0
Lysimachia thyrsiflora	1	tr	5	1	0	0	0	0
Medicago lupulina	0	0	0	0	19	2	23	2
M. sativa	0	0	0	0	1	tr	0	0
Melilotus alba	0	0	0	0	3	tr	8	2
M. officinalis	0	0	0	0	0	0	1	tr
Mentha arvensis	0	0	2	tr	0	0	0	0
Onosmodium molle	0	0	0	0	1	tr	0	0
Oxalis violacea	0	0	0	0	13	1	0	0
Panicum virgatum	0	0	1	1	2	1	1	tr
Phalaris arundinacea	0	0	1	tr	0	0	0	0
Physalis virginiana	0	0	0	0	1	tr	4	tr
Poa compressa	0	0	1	tr	1	tr	4	tr
P. palustris	0	0	2	1	0	0	0	0
P. pratenis	0	0	8	2	46	63	46	63
Polygonum amphibium var. emersum	33	11	16	4	0	0	0	0
Potentilla anserina	0	0	7	1	0	0	0	0
P. arguta	0	0	0	0	3	1	1	tr
Psoralea argophylla	0	0	0	0	0	0	5	1
P. esculenta	0	0	0	0	0	0	1	tr
Ranunculus rhomboideus	0	0	1	tr	2	tr	0	0
Ratibida columnifera	0	0	0	0	2	tr	0	0
R. pinnata	0	0	0	0	0	0	4	tr
Rosa acicularis	0	0	0	0	0	0	1	tr
Scirpus pallidus	0	0	4	1	0	0	0	0
Scolochloa festucacea	24	7	0	0	0	0	0	0
Sium suave	0	0	1	tr	0	0	0	0
Solidago canadensis	0	0	1	tr	40	12	30	8
S. rigida	0	0	0	0	25	4	39	12
Sorghastrum nutans	0	0	0	0	6	5	0	0
Sparganium eurycarpum	14	2	13	2	0	0	0	0
Spartina pectinata	2	1	26	17	0	0	0	0
Sporobolus heterolepis	0	0	0	0	0	0	3	1
Stachys palustris	2	tr	5	tr	0	0	0	0

Table 32 Cont.

	Wetland				Upland			
Transect:	Seasonal		Temporary		Lower		Upper	
Species	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)
Stipa spartea	0	0	0	0	16	3	26	6
S. viridula	0	0	0	0	6	2	14	5
Symphoricarpos occidentalis	0	0	0	0	5	1	1	tr
Taraxacum officinale	0	0	0	0	2	tr	4	tr
Teucrium canadense	0	0	5	1	0	0	0	0
Tragopogon dubius	0	0	0	0	2	tr	0	0
Verbena stricta	0	0	0	0	3	tr	4	tr
Viola spp.	0	0	1	tr	0	0	0	0
V. pedatifida	0	0	0	0	11	tr	14	tr
Zigadenus elegans	0	0	0	0	5	tr	1	tr
Zizia aptera	0	0	0	0	1	tr	0	0

[a]See methods section in Chapter 6 for transect definitions.

Table 33. Growing season-long means of canopy coverage estimates (C) (percent) and frequencies of occurrence (F) (number of plots occurred in) of species at Site 2. (n = 48).

	Wetland				Upland			
Transect[a]:	Seasonal		Temporary		Lower		Upper	
Species	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)
Achillea millefolium	0	0	0	0	20	1	24	3
Agropyron smithii	0	0	0	0	34	6	15	4
A. trachycaulum	0	0	0	0	25	6	35	8
Alisma subcordatum	2	tr	0	0	0	0	0	0
Ambrosia artemisiifolia	0	0	4	tr	0	0	0	0
A. psilostachya	0	0	0	0	1	tr	0	0
Andropogon gerardii	0	0	0	0	22	10	23	9
A. scoparius	0	0	0	0	37	16	39	17
Anemone cylindrica	0	0	0	0	7	tr	8	tr
A. patans	0	0	0	0	16	tr	24	1
Antennaria neglecta	0	0	0	0	0	0	1	tr
Artemisia ludoviciana	0	0	0	0	3	tr	6	1
Asclepias spp.	0	0	0	0	2	tr	1	tr
A. ovalifolia	0	0	0	0	1	tr	3	tr
Aster ericoides	0	0	2	tr	27	4	36	7
A. hesperius	1	tr	24	7	0	0	0	0
Astragalus spp.	0	0	0	0	2	tr	0	0
A. agrestis	0	0	0	0	3	tr	0	0
Bouteloua curtipendula	0	0	0	0	33	8	35	7
Calamagrostis canadensis	0	0	7	2	0	0	0	0
C. stricta	1	tr	33	17	0	0	0	0
Calylophus serrulatus	0	0	0	0	0	0	1	0
Carex spp.	1	tr	45	58	30	5	22	3
C. atherodes	47	72	30	32	0	0	0	0
Cirsium arvense	0	0	0	0	2	tr	8	1
C. flodmanii	0	0	0	0	1	tr	2	tr
Dicanthelium leibergii	0	0	0	0	2	tr	1	tr
Eleocharis compressa	0	0	0	0	0	0	1	tr
E. palustris	23	4	46	22	0	0	0	0
Equisetum sp.	0	0	1	tr	6	tr	0	0
Gaura coccinea	0	0	0	0	0	0	1	tr
Geum triflorum	0	0	0	0	1	tr	1	tr
Glycyrrhiza lepidota	0	0	1	tr	1	tr	0	0
Hordeum jubatum	0	0	3	tr	0	0	0	0
Juncus balticus	0	0	10	6	0	0	0	0
J. torryi	0	0	1	tr	0	0	0	0
Koeleria pyramidata	0	0	0	0	1	tr	5	tr

Table 33 Cont.

	Wetland				Upland			
Transect:	Seasonal		Temporary		Lower		Upper	
Species	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)
Lathyrus palustris	0	0	10	1	0	0	0	0
Lithospermum canescens	0	0	0	0	13	1	15	1
Lycopus americanus	0	0	4	tr	1	tr	0	0
L. asper	1	tr	22	3	1	tr	0	0
Medicago lupulina	0	0	1	tr	11	tr	8	tr
Mentha arvensis	1	tr	3	tr	0	0	0	0
Oxalis violacea	0	0	0	0	5	tr	2	tr
Panicum virgatum	0	0	2	1	0	0	1	tr
Physalis virginiana	0	0	0	0	1	tr	6	tr
Polygonum amphibium var. *emersum*	16	5	12	6	0	0	0	0
Potentilla anserina	0	0	15	2	0	0	0	0
P. arguta	0	0	0	0	1	tr	1	tr
Poa compressa	0	0	0	0	0	0	1	tr
P. palustris	0	0	1	tr	0	0	0	0
P. pratensis	0	0	14	3	47	63	48	69
Psoralea argophylla	0	0	0	0	2	1	0	0
P. esculenta	0	0	0	0	1	tr	0	0
Ranunculus scleratus	1	tr	0	0	0	0	0	0
Scolochloa festucacea	1	tr	0	0	0	0	0	0
Senecio pseudaureus	0	0	2	tr	0	0	0	0
Solidago canadensis	0	0	2	tr	38	14	35	14
S. rigida	0	0	0	0	13	1	32	6
Sonchus arvensis	0	0	1	tr	0	0	0	0
Sorghastrum nutans	0	0	0	0	4	1	0	0
Sparganium eurycarpum	40	16	15	5	0	0	0	0
Spartina pectinata	0	0	31	12	2	1	0	0
Sporobolus heterolepis	0	0	0	0	1	tr	2	tr
Stachys palustris	2	tr	9	1	0	0	0	0
Stipa spartea	0	0	0	0	13	2	20	4
S. viridula	0	0	0	0	11	5	9	2
Symphoricarpos occidentalis	0	0	0	0	3	tr	2	tr
Taraxacum officinale	1	tr	1	tr	6	tr	2	tr
Teucrium canadense	2	tr	5	tr	0	0	0	0
Tragopogon dubius	0	0	0	0	0	0	1	tr
Verbena stricta	0	0	0	0	6	tr	2	tr

Table 33 Cont.

	Wetland				Upland			
Transect:	Seasonal		Temporary		Lower		Upper	
Species	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)	F (#)	C (%)
Viola pedatifida	0	0	0	0	9	tr	9	tr
Zigadenus elegans	0	0	0	0	4	tr	3	tr

[a]See methods section in Chapter 6 for transect definitions.

Table 34. Comparison of growing season (1985) means (n = 48) of wetland and upland above ground standing crops in 2 seasonal-wetland-dominated basins in Deuel County, South Dakota (additional statistics are listed in Appendix C).

	Standing crop[a] ($g \cdot m^{-2}$)	
Transect	Site 1	Site 2
Seasonal wetland	587 a	381 b
Temporary wetland	500 b	474 a
Upland - lower	259 c	297 c
Upland - upper	239 c	284 c

[a]Means followed by a different letter within the same column are significantly different ($p<0.05$).

Additionally, the S.W. transect significantly out-yielded the T.W. transect. At Site 2, the wetland transects again significantly out-yielded the upland transects, although the differences were not quite so great. The T.W. transect at Site 2, however, significantly out-yielded the S.W. transect. Other studies conducted in the northern prairie area have also shown increased production in wetland sites versus upland. Cosby (1964) found annual herbage production in seasonal wetland in northwest North Dakota (slough sedge - whitetop dominated; Parnell soil) to range from about 1.5 times to over 2 times the production of the highest producing upland soil (native mixed grass prairie; Bonilla soil) of the catena. In the Red River Valley of northwest Minnesota, Smeins and Olsen (1970) also found wetland plant communities yielded about 1.5 to 2.0 times more than uplands in native tall grass prairie. Barker and Erickson (1980) reported that a temporary wetland community (_Carex_ - _Juncus_ - _Spartina_) out-yielded the upland prairie in North Dakota by 1.3 to 1.6 times. Bernard (1974) found that a _Carex rostrata_ dominated wetland greatly out produced the adjacent Kentucky bluegrass old-field in central Minnesota.

The reversal in ranking of the season means of standing crop for the T.W. and S.W. transects at the 2 sites is probably indicative of the unstable nature of the environment in prairie pothole wetlands. The data in Table 34 are very similar between sites for all transects except the S.W. The yield at Site 2 for the S.W. transect was much less than at Site 1. Small variations in hydrology or soil organic matter content could influence redox relationships in the soil and result in variable effects on site fertility as well as the overall chemical mileau of the sites. Fulton et al. (1979) found wide between site variation of wetland plant communities.

The IVDOM of the alfalfa standards in each run of the procedure are listed in Table 35. These data show that, overall, the IVDOM data are probably underestimates and that the extreme values for each standard span a fairly large range. However, the season-long means are being statistically compared and all samples from each clipping session were assayed in the same run. Thus, between run variation will be compounded with between date variation in the ANOVA, but between transect relationships should be little affected.

The relationship between the season-long IVDOM means for the transects are shown in Table 36. At each site, all transects were significantly different from each other and all were ranked in the same order: U.U., U.L., S.W., and T.W. Although the wetlands can outproduce the uplands in terms of quantity, the digestibility of the wetland communities is less.

The trends in CP content of the vegetation were not as consistent (Table 37) nor as clear-cut as those for digestibility. At Site 1 the U.U. transect averaged the highest in CP, but at Site 2 it was the S.W. transect. The T.W. transect, however, was consistent in that at both sites it had the lowest CP content. It may be that N may be more severely limiting at that landscape position than at the others. A possible explanation may be that the T.W. transect is situated at a location that may be subjected to a more frequent alternation of wet and dry periods than points above or below it on the landscape; at least during the course of the present study. Thus, the frequency with which

Table 35. Mean IVDDM (percent of dry matter at 100°C, n = 3 per run) of alfalfa standards included in each run of samples collected in the wetland versus upland forage study.

Run	Low standard (%)	High standard (%)
1	53.4	67.7
2	55.3	66.1
3	55.4	66.9
4	54.8	66.9
5	54.5	67.0
6	59.8	70.3
7	55.8	69.1
8	54.7	66.0
9	56.6	69.5
Mean:	55.6 (0.6)[a]	67.7 (0.5)
Reported value:	60.0	73.9
Mean deviation from reported value:	-4.4	-6.2

[a]Standard error in parentheses.

Table 36. Comparison of growing season (1985) means (n = 48) of IVDDM in wetland and upland plant communities in 2 seasonal-wetland-dominated basins in Deuel County, South Dakota (additional statistics are listed in Appendix C).

	IVDDM[a] (% of dry matter)	
Transect	Site 1	Site 2
Seasonal wetland	43.1 c	41.9 c
Temporary wetland	39.0 d	37.7 d
Upland - lower	45.2 b	44.5 b
Upland - upper	47.1 a	46.2 a

[a]Means followed by a different letter within the same column are significantly different ($p<0.05$).

Table 37. Comparison of growing season (1985) means (n = 48) of crude protein content in wetland and upland plant communities in 2 seasonal-wetland-dominated basins in Deuel County, South Dakota (additional statistics are listed in Appendix C).

	Crude protein[a] (% of dry matter)	
Transect	Site 1	Site 2
Seasonal wetland	8.3 b	9.4 a
Temporary wetland	7.6 c	7.7 c
Upland - lower	8.2 b	7.9 bc
Upland - upper	9.1 a	8.2 b

[a]Means followed by a different letter within the same column are significantly different ($p<0.05$).

the soil redox status passes through the range most favorable for denitrification (see Lindsay 1979) could be higher than at other landscape positions. As found in the present study, Erickson et al. (1980) found that in comparison with the upland communities (native prairie), temporary wetland yielded forage of lower CP and higher fibrous material.

Conclusions

The season-long comparisons of standing crop, CP, and IVDDM of wetlands and uplands show that wetland definitely produce more forage, in terms of biomass, than the uplands in an undisturbed native prairie situation. Although CP relationships are not clear-cut, the digestibility of wetland forage is definitely lower, on the average, than native upland forage.

Chapter 7

SUMMARY AND CONCLUSIONS

From the results of these investigations and the information available in the literature, it is apparent that seasonal wetlands and seasonal-wetland-dominated basins in the Prairie Pothole Region can produce large amounts of forage (per unit area), but the forage may be less digestible than most upland forages, as a group. On an individual basis, the dominant graminoids of seasonal wetlands, such as whitetop and slough sedge, are similar to tame grasses at similar stages of maturity. Many of the graminoid species occurring in temporary wetlands, however, appear to be poor in CP and digestibility in relation to other species. Slough sedge maintains a better nutritional quality for a longer period during the growing season than most wetland species. Many subordinate wetland forbs seem to be very high in IVDDM and CP and may be candidates for breeding programs designed to produce species for use in wetland sites. Palatability information is lacking, however, for most of these species.

The best quality forage is produced in wetlands early in the growing season, just as it is on the uplands. Therefore, sacrificing quantity to get a better quality forage is an option for producers. The utilization of slough sedge at immediate-post-seed-fill and whitetop at seed-fill would be desirable because at these times the low-point in the below-ground energy reserves is past and CP and IVDDM are still at acceptable levels. On the other hand, burreed, a species that is apparently unpalatable, might be managed against by a destructive treatment at the onset of flowering; the time of the lowest below-ground energy reserves.

A good practice to be followed by any livestock producer is to have hay analyzed for CP content at a private or state feed analysis lab. If the CP content is known, wetland hay may be utilized the same as any other hay in feeding programs; protein deficiencies in the roughage can easily be corrected for by adjustment of concentrate in the ration.

Although the nutritional quality of wetland forage may not be as high as many upland forages, the quantity produced in these systems is large. Using these wetlands for their forage, rather than draining them and planting them to cultivated annual crops, allows the landowner to economically use them without significantly impacting the functions that these wetlands perform for society at large.

Future research efforts on wetland forages should concentrate on intensity and timing of utilization in relation to yield and effects on stand integrity. Both utilization by mowing and grazing need to be assessed since response by various species to method of utilization may be different.

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APPENDICIES

Appendix A. Additional statistics for nested analysis of variance of late-summer standing crops and standing litter in mowed versus control treatments at Sites 4, 5, and 6 in Deuel County, South Dakota in 1984 (means listed in Table 29).

Source	df	Mean squares
Site 4, standing crop		
Treatment	1	221449.0*
Replications(treatment)	4	14887.0
Error	30	32862.2
Total	35	36196.1
Site 4, standing litter		
Treatment	1	6501.7**
Replications(treatment)	4	286.1
Error	30	261.5
Total	35	442.6
Site 5, standing crop		
Treatment	1	25589.9*
Replications(treatment)	4	3720.5
Error	14	4230.3
Total	19	5266.9
Site 5, standing litter		
Treatment	1	992.6
Replications(treatment)	4	253.4
Error	14	123.9
Total	19	191.9
Site 6, standing crop		
Treatment	1	34555.8
Replications(treatment)	8	13059.7
Error	25	13975.8
Total	34	14365.6

Appendix A Cont.

Source	df	Mean squares
Site 6, standing litter		
Treatment	1	4244.9**
Replications(treatment)	8	371.5
Error	25	225.8
Total	34	372.2

* Significant at $p<0.05$ (F test).
** Significant at $p<0.01$ (F test).

Appendix B. Additional statistics for nested analysis of variance of IVDDM, ash, and CP content of species in mowed versus control treatments at Sites 4, 5, and 6 in Deuel County, South Dakota in 1984 (means listed in Table 31).

Source	df	Mean squares		
		Ash	CP	IVDDM
Site 4, slough sedge				
Treatment	1	7.631	0.2888	56.57
Replications(treatment)	4	3.655	1.1654	14.64
Error	12	1.116	2.9385	22.81
Total	17	2.096	2.3655	22.88
Site 4, litter				
Treatment	1	120.64	2.4568	0.2427
Replications(treatment)	4	26.84	30.4940	27.0155
Error	12	13.90	5.8496	35.8667
Total	17	23.23	11.4487	31.6885
Site 5, slough sedge				
Treatment	1	0.0773	0.0060	154.912
Replications(treatment)	4	0.2734	1.0486	57.322
Error	8	0.1479	0.7867	3.067
Total	13	0.1811	0.8025	30.476
Site 5, whitetop				
Treatment	1	0.0060	1.4593*	2.871
Replications(treatment)	4	0.2198	0.0642	5.765
Error	8	0.0646	0.2353	5.876
Total	13	0.1079	0.2799	5.610
Site 5, litter				
Treatment	1	3.482	0.6703	2.708
Replications(treatment)	4	30.157	8.0310	37.511
Error	7	26.960	1.8291	47.849
Total	12	26.069	3.5235	40.642

Appendix B Cont.

		Mean squares		
Source	df	Ash	CP	IVDDM
		Site 6, slough sedge		
Treatment	1	0.0039	1.1078	4.558
Replications(treatment)	7	2.5581	3.9242*	11.153
Error	7	1.4487	0.9311	29.540
Total	15	1.8701	2.3397	19.294
		Site 6, whitetop		
Treatment	1	10.1728	7.0569*	110.61
Replications(treatment)	8	2.0202*	1.0037	27.74
Error	12	0.5217	0.9268	16.10
Total	21	1.5293	1.2468	24.86
		Site 6, litter		
Treatment	1	21.344	8.719	5.146
Replications(treatment)	8	11.839	2.669	35.100*
Error	12	6.884	2.811	9.264
Total	21	9.385	3.041	18.910

* Significant at $p<0.05$ (F test).

Appendix C. Additional statistics for analyses of variance (4 x 8 factorial arraingment) of standing crop, CP content, and IVDDM of wetland and upland plant communities in 2 seasonal-wetland-dominated basins in Deuel County, South Dakota in 1985 (means listed in Tables 34, 36, and 37).

		Mean squares[a]		
Source	df	Standing crop	CP	IVDDM
		Site 1		
Model	31	360051	55.77	737.2
Transect	3	1451602	19.72	583.0
Date	7	715436	223.66	2830.7
Transect X date	21	85653	4.9617	61.38
Error	160	16930	0.7022	10.37
Total	191	72620	9.6406	128.34
		Site 2		
Model	31	143986	39.33	654.4
Transect	3	371396	28.13	651.7
Date	7	407744	152.38	2493.7
Transect X date	21	23580	3.249	41.70
Error	160	11138	1.190	11.79
Total	191	32700	7.380	116.1

[a] All main effect and interaction means squares are highly significant ($p<0.005$, F test).